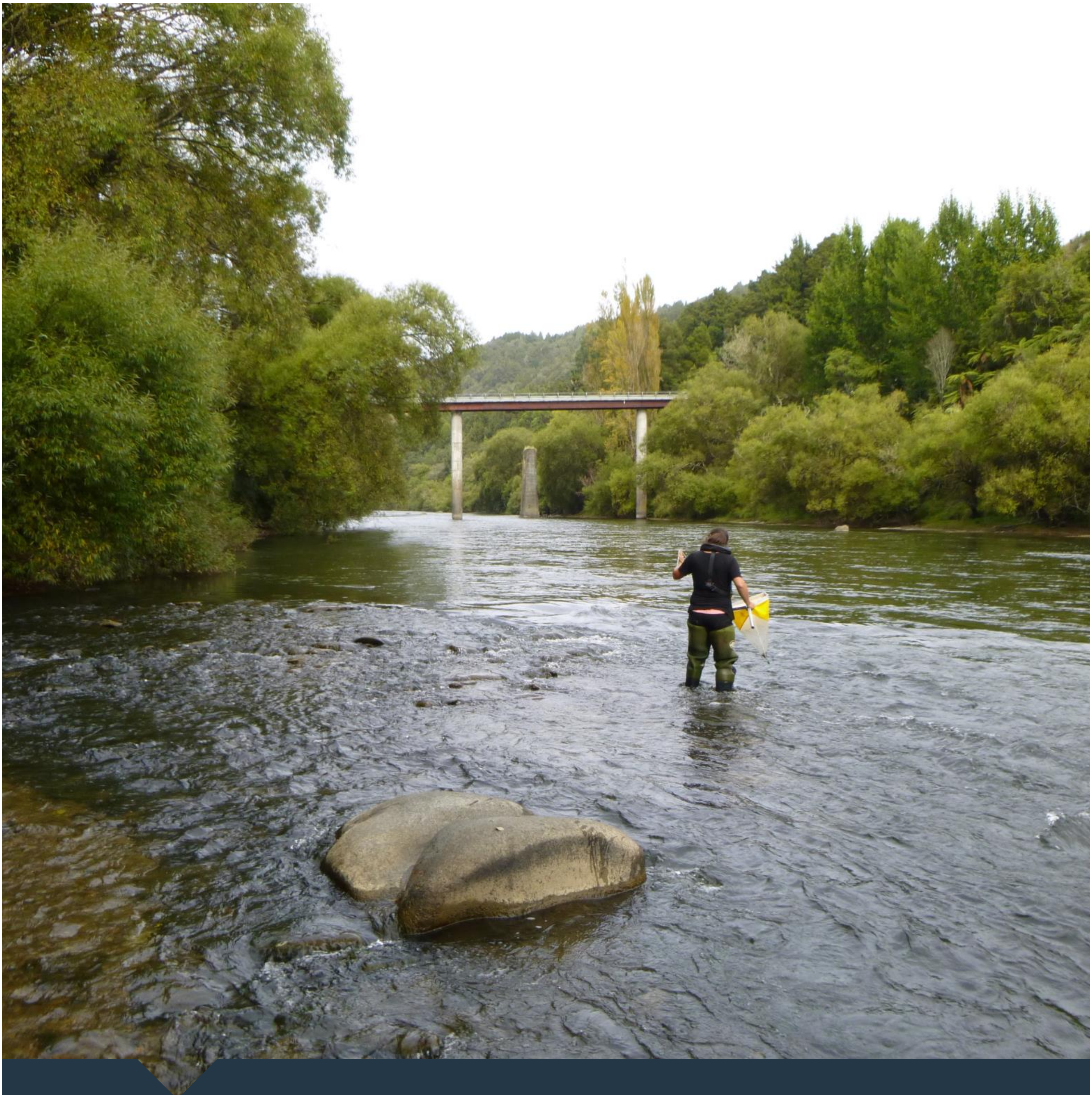

State and trends for water quality in rivers, lakes, coastal and estuary sites in the Manawatū-Whanagnui Region

For the period ending 30 June 2022

September 2023

horizons
REGIONAL COUNCIL

Prepared for:

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September 2023
Report No. 2023/EXT/1824
ISBN 9781991061416

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LWP Client Report Number: 2023-10

Report Date: September 2023

LWP Project:

Quality Assurance Statement

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Version	Reviewed By	
FINAL	Ton Snelder	

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Executive Summary

This study analysed the available water quality data for rivers, lakes, estuaries, and coastal in the Manawatū-Whanganui Region. The state of water quality in the region is reported on a site-by-site basis, relative to targets set in the One Plan (Horizons Regional Council, 2014). In addition, the study assessed water quality trends site by site, reporting both for individual sites and variables, and as regional aggregates for each water quality variable.

We analysed water quality data representing 19 physico-chemical and microbiological variables and biological indicators (see Table 1 for variable names and abbreviations) for 207 monitoring sites in the region. The monitoring sites included river (181), coastal (4), estuary (7) and lake (15) locations. River sites were further categorised as State of the Environment - SoE (representative sites), impact (sites immediately downstream of known discharges) and discharge (effluent) sites. State and trends were evaluated for site type and variable combinations that had an associated One Plan target. Sites were graded as 'pass' or 'fail' for each variable based on a comparison of the assessed state with the One Plan criteria.

A trend assessment was carried out for 10-year, 20-year and 30-year periods to 30 June 2022 for all site and water quality variable combinations that met a minimum requirement for numbers of observations. The methods used for statistical trend analyses are Kendall's test of rank correlation and the Sen slope estimator (SSE), which have both been used for trend analysis of water quality for several decades (Hirsch et al., 1982). Individual site trend assessments were aggregated, to provide an overall picture of trends for the region. This was done graphically using stacked bar charts showing proportions of sites for each variable that fall into different trend direction confidence categories.

Water quality state

The most obvious pattern associated with the assessment of water quality state was that for many variables the individual sites almost uniformly passed or failed One Plan criteria. A majority of river sites failed the Horizons One Plan criteria for dissolved reactive phosphorus (DRP), macroinvertebrate community index (MCI), *E. coli* and clarity. Conversely, almost all sites passed the One Plan criteria for ammoniacal-N (NH4-N), periphyton (mats) and dissolved oxygen (sat). There were similar numbers of State of Environment (SoE) sites passing and failing the One Plan criteria for chlorophyll-*a*, particulate organic matter (POM), periphyton (filaments) and soluble inorganic nitrogen (SIN) Generally, these patterns in grades were similar for the impact sites. A majority of discharge sites failed the One Plan criteria for change in pH, and percent reduction in clarity. Conversely, most discharge sites the passed the change in temperature criterion.

All lakes sites failed the total nitrogen (TN) criterion, and only Lake Koitiata passed the chlorophyll-*a* and total phosphorus (TP) criteria. Grades varied across the region for the *E. coli* (bathing) criteria. For estuary sites, all sites failed *E. coli* criteria and passed NH4-N criteria and for coastal sites, all sites based the NH4-N criteria and failed the TN, TP and enterococci (bathing) criteria.

There are no immediately obvious geographic patterns associated with the variation in grades, however this does not mean that there are not associations with, for example, river size or catchment land cover. Summaries of the proportion of sites (by monitoring site type) that passed or failed the one plan criteria are shown in Figure A.

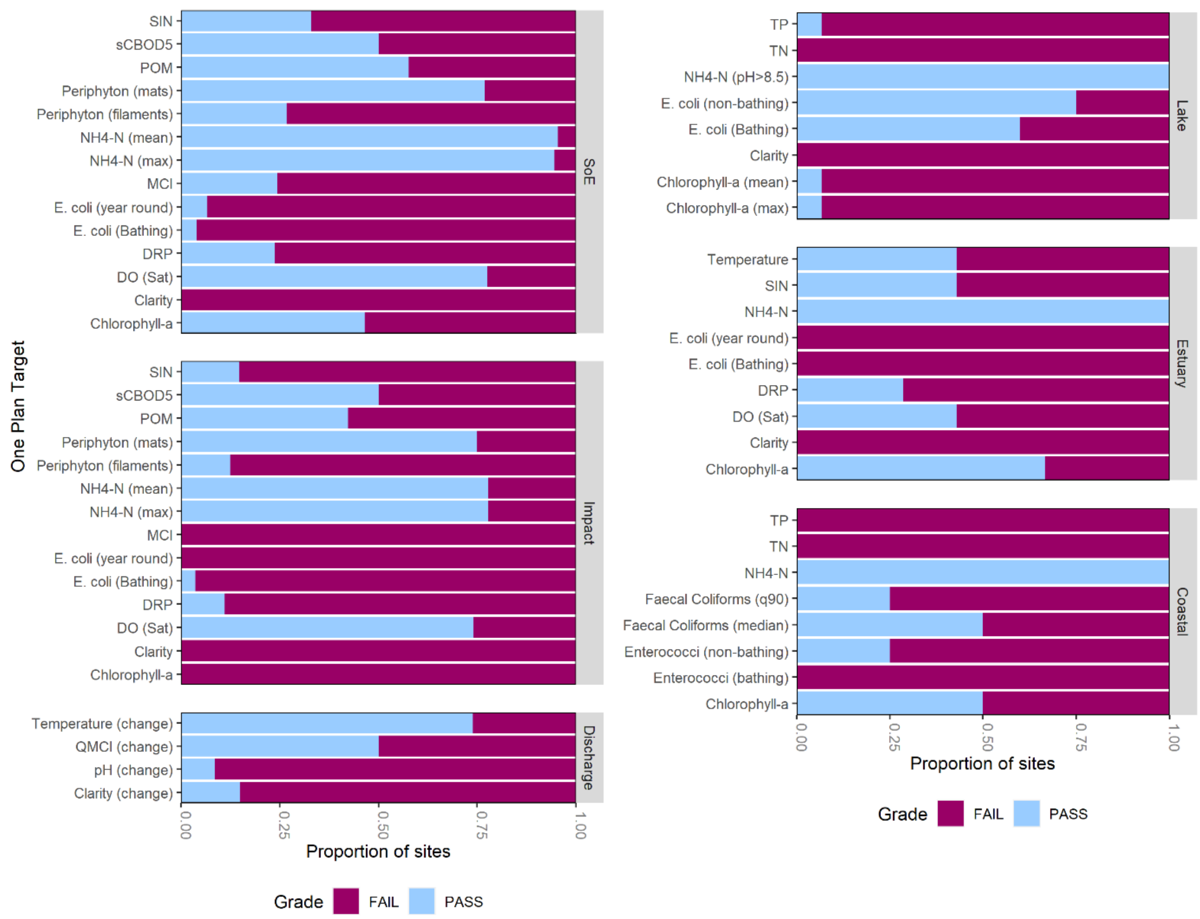

Figure A: Summary of proportions of sites (by monitoring type) that pass or fail One Plan targets.

Water quality trends

Water quality trends for the 10 year period were assessed for up to 100 (of 112) river SoE sites, 27 (of 27) river impact sites, 24 (of 34) discharge sites, 4 (of 15) lake sites, 6 (of 7) estuary sites and 4 (of 4) coastal sites. Water quality trends for the 20 year period were assessed at up to 28 (of 112) river SoE sites and 2 (of 34) discharge sites. There were insufficient data to calculate 20 year trends at any lake, estuary, coastal or river impact sites. Water quality trends for the 30 year period were also calculated for up to 6 river SoE sites. The difference in numbers of sites between time periods and between total numbers reflects the significant expansion of Horizons Regional Council's river monitoring network over the period 2007-2010, and the lake monitoring network in recent years.

Figure B shows stacked bar charts showing aggregate trends (i.e., proportions of river sites in different trend direction confidence categories) for each variable. There was an insufficient number of sites to evaluate aggregate trends for lakes, coastal and estuaries. For the 10 year period and river SoE site trends, seven of the 15 water quality variables had more than half of sites categorised as "likely degrading" or "Very likely degrading" (Chlorophyll *a* (Chl_a), visual clarity (CLAR), DRP, MCI, NH4N, periphyton mats (Peri_mats), and SIN), whereas only two variables had more than half of sites classes as "likely improving" or "very likely improving" (Dissolved oxygen (DO_Sat) and 5 day soluble carbonaceous biochemical oxygen demand (sCBOD5)). It is particularly noted that in previous trend assessments (and over the 20 year trend period) NH4N was dominated by improving trends. However, the majority of the NH4N trends are evaluated as having a Sen slope of zero (i.e., below the rate of detection given by the detection limit and time period).

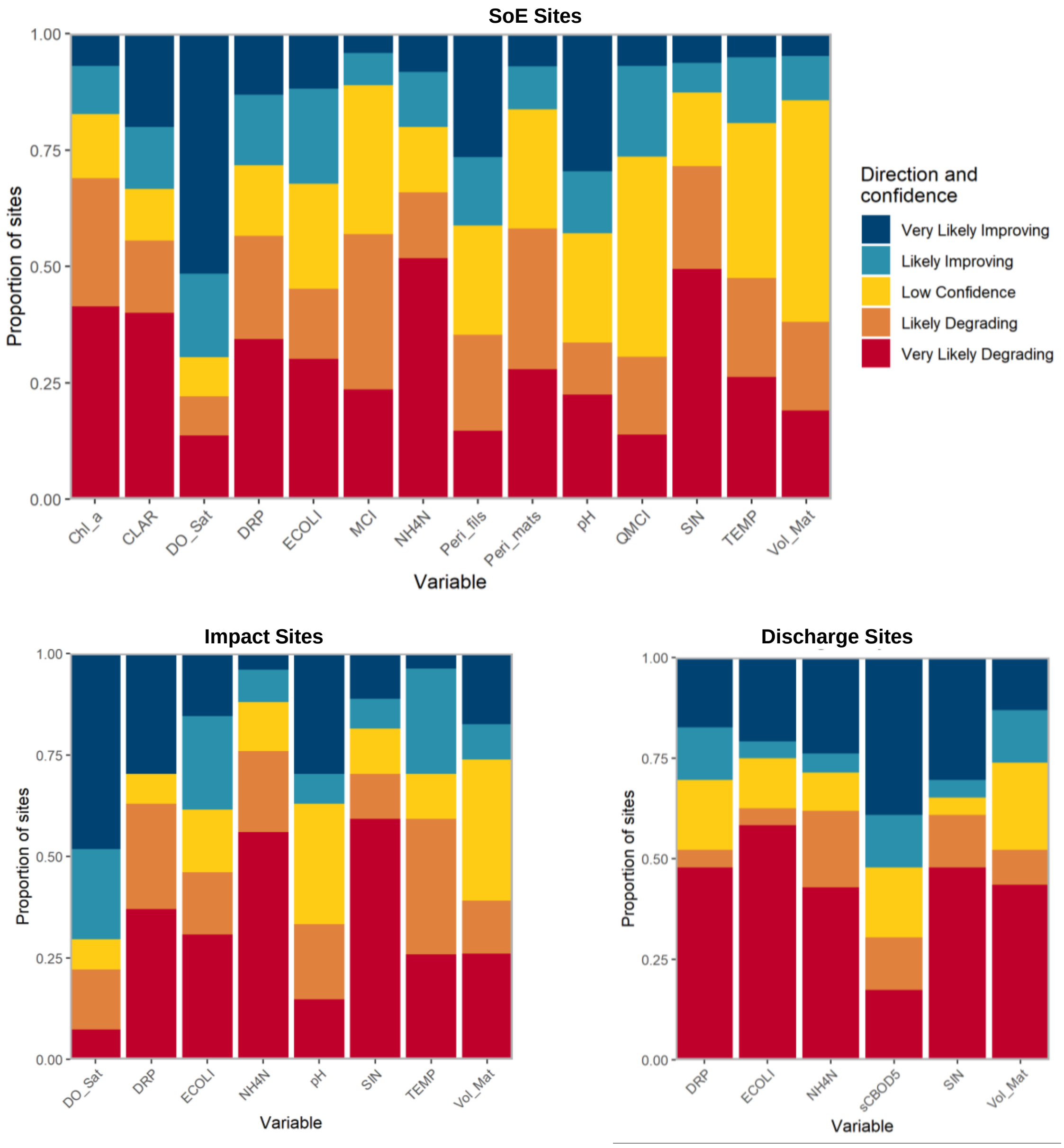

Figure B. Summary plot representing the aggregated proportion of 10-year time period trends for river (SoE, impact and discharge) sites at each categorical level of confidence and direction . The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

Relationships between state and trends

For river and lake sites, the trends with the largest rates of degradation were associated with sites with poor state grades, almost uniformly across all variables. For *E. coli* in rivers, the largest improving trend rates were at sites that failed the One Plan criteria. At estuary sites, all but one site that failed the One Plan *E. coli* criteria had improving trends for *E. coli*. At both lakes and estuaries there was a pattern of larger degrading trend rates with larger (worse) water quality (based on compliance statistics). Trends in chlorophyll-*a* at coastal sites indicated improvement, both for sites that passed and failed the One Plan chlorophyll-*a* criterion.

1 Introduction

Horizons Regional Council operates an extensive network of water quality and flow monitoring sites throughout the Manawatū-Whanganui Region for monitoring the state and trends in water quality and reporting on policy effectiveness. Prior to mid-2007, there were fewer monitoring sites in the Region (Roygard et al., 2011). Following a review, a more extensive and detailed monitoring programme commenced for rivers in mid-2007 and was rolled out over three years. Since that date, a suite of variables, including physico-chemical and microbiological variables and biological indicators have been measured at 207 sites in the region. These data represent river (State of Environment (SoE), point source discharges and impact), lake (commenced 2014), estuary and coastal (beach) (commenced 2011) monitoring sites.

This study analysed the available water quality data for rivers, lakes, estuaries, and coast in the Manawatū-Whanganui Region. The state of water quality in the region is reported on a site by site basis, relative to targets set in the One Plan (Horizons Regional Council, 2014). In addition, the study assessed water quality trends site by site, and across the region as a whole.

2 Data

2.1 Water quality data

Water quality data were obtained representing physico-chemical variables, microbiological variables and biological indicators (Table 1) for 207 monitoring sites in the region from the Horizons database. These included river (181), coastal (4), estuary (7) and lake (15) sites (Figure 1).

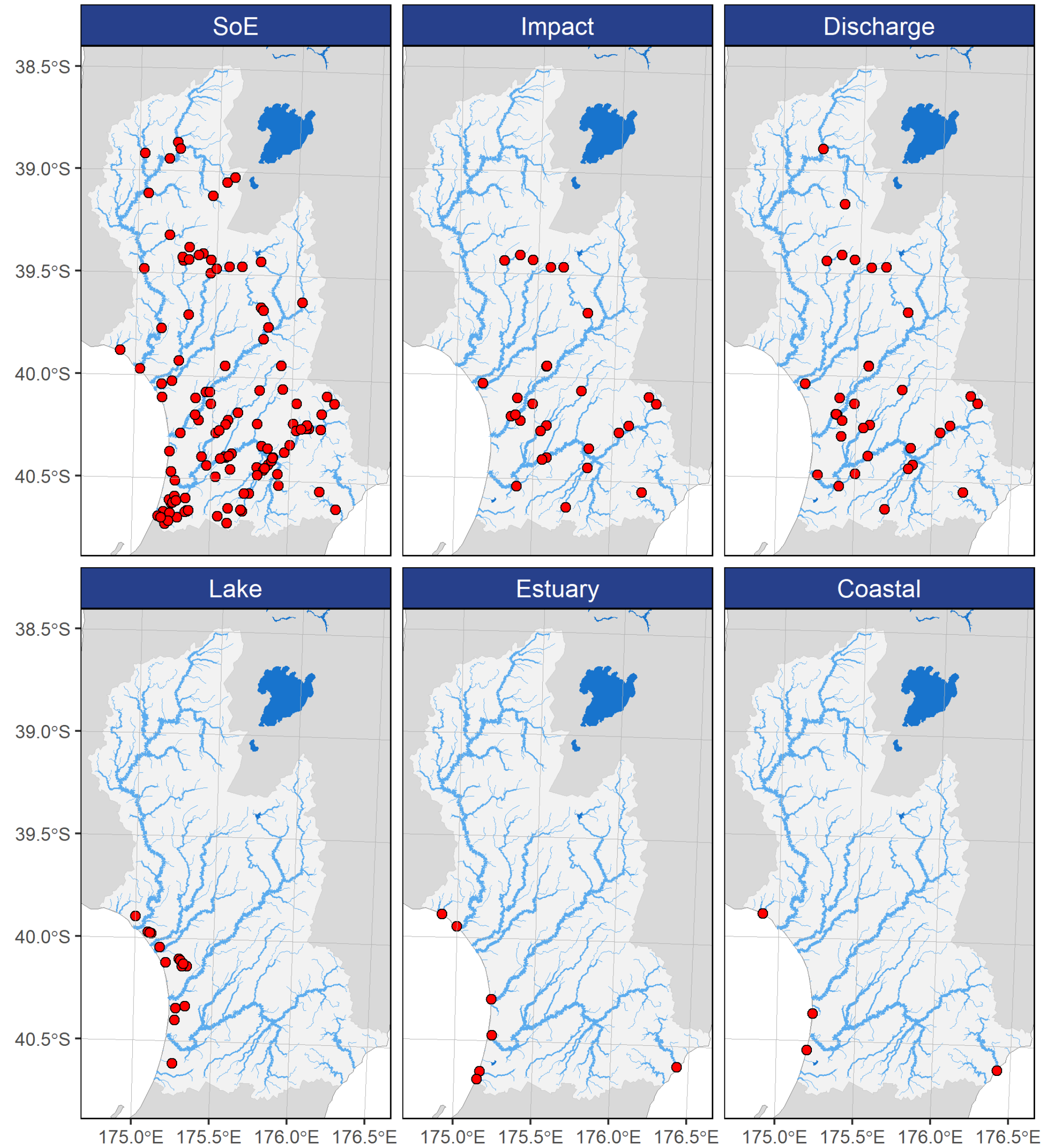

Figure 1: Locations of river (top row), lake, estuary and coastal monitoring sites in the Manawatu-Whanganui region that were included in this study.

River sites were categorised into three types: discharge, impact and state of environment (SoE) (Figure 4). Discharge and impact sites represent specific point source discharges or locations downstream (at the end of the consented mixing zone) of significant and specific point sources, respectively. It has been assumed SoE sites are not significantly affected by point source discharges and that they reflect both state and trends arising from the combination of diffuse and point sources of contaminants occurring in their catchments. Therefore, SoE sites were assumed to be representative of general regional river water quality conditions. The three categories of river sites were analysed separately in the study.

Table 1: Water quality variables, measurement units and site numbers (by monitoring type) included in this study.

Variable type	Variable name	Description	Units	Monitoring site numbers by type					
				SoE	Impact	Discharge	Lakes	Estuary	Coastal
Physico- Chemical	CLAR	Black Disc Visibility	m	110	27	2	4	1	0
	DO_Sat	Field Dissolved Oxygen Saturation	%	112	27	10	0	7	0
	DRP	Dissolved Reactive Phosphorous	g m^{-3}	112	27	34	0	7	0
	NH4N	Ammoniacal Nitrogen	g m^{-3}	112	27	34	15	7	4
	pH	Field pH	pH	112	27	10	0	1	0
	Vol_Mat	Volatile Matter	g m^{-3}	88	28	34	0	1	0
	SIN	Soluble Inorganic Nitrogen	g m^{-3}	112	27	34	0	7	0
	Temp	Field Temperature	ºC	112	27	30	0	7	0
	TN	Total Nitrogen	g m^{-3}	0	0	0	15	0	4
	TP	Total Phosphorous	g m^{-3}	0	0	0	15	0	4
Micro-biological	Ecoli	*E. coli* by MPN	MPN $100mL^{-1}$	110	27	34	15	7	0
	Entci[a]	Enterococci	MPN $100mL^{-1}$	0	0	0	0	0	4
	COLIF	Faecal Coliforms	MPN $100mL^{-1}$	0	0	0	0	0	4
Biological	Chl_a[a]	Chlorophyll-*a* (planktonic)	mg Chl-a m^{-3}	0	0	0	15	6	4
	Chl_a	Chlorophyll-*a* (benthic)	mg Chl-a m^{-2}	60	9	0	0	0	0
	Peri_Fils	Filamentous Periphyton cover	%	61	10	0	0	0	0
	Peri_Mats	Mat Periphyton Cover	%	61	10	0	0	0	0
	MCI	Macroinvertebrate Community Index	MCI	80	7	0	0	0	0
	QMCI	Quantitative Macroinvertebrate Community Index	QMCI	80	7	0	0	0	0

2.2 Flow data

Many of the water quality monitoring sites were associated with flow records, which were also obtained from the Horizons database for 123 sites. Flow was needed for the state assessment as some of the environmental targets apply only when flows are in a certain range (see Section 3.2.1). There were two types of flow ranges used in the targets: below the 20th flow exceedance percentile (FEP) (4 targets for rivers, 3 targets for estuaries); and below the median flow (2 targets for each of rivers and estuaries). Horizons regional council staff estimated the relevant flow percentiles and assigned each daily observation of flow to one of three flow categories: (1) "below median"; (2) "median to 20th FEP"; and (3) "flood". There were 36 flow sites with an associated water quality sites that had flow categories assigned. There were no flow records provided for estuaries.

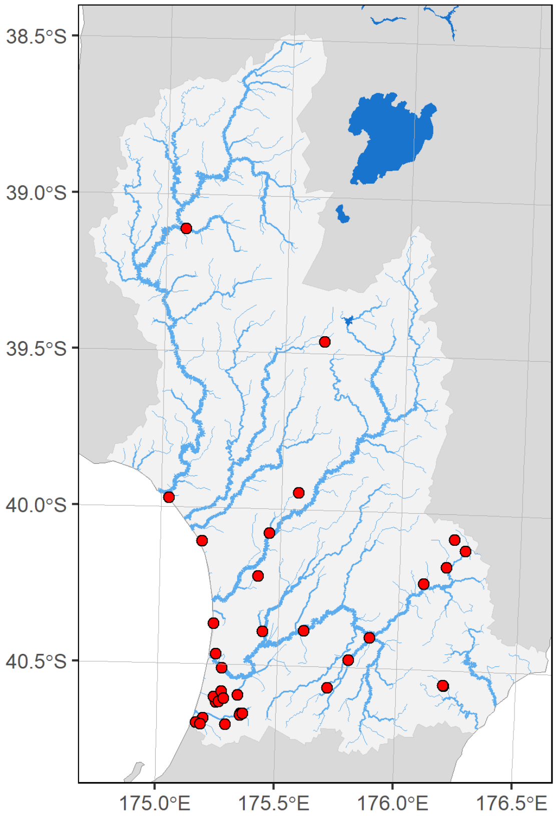

Figure 2: Map of flow monitoring locations with an associated water quality monitoring site and assigned flow categories.

3 Methods

3.1 State analysis

3.1.1 Grading of monitoring sites

Sites are graded based on comparing a compliance statistic against Horizons One Plan targets (Table 2; Horizons Regional Council, 2014). For each One Plan target, a "compliance statistic" is calculated and compared to the target e.g., for a site, the mean of ammoniacal-nitrogen is calculated from the water quality record (the compliance statistic) and evaluated as passing or failing, depending on whether the compliance statistic is less than or greater than the One Plan target of 0.4 or 0.32 mg/l (the criteria, which varies by site), respectively. It is noted that, depending on the variable, the observations needed to be either lower than the threshold (e.g., all chemical concentration targets, periphyton abundance targets) or greater than the threshold (e.g., clarity and MCI targets). In the cases where the compliance statistic is a quantile (i.e., the median or 90th percentile), the Hazen method was used to calculate the appropriate quantile, following the recommendation in the New Zealand Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for Environment & Ministry of Health, 2003).

The numeric values for Horizons One Plan targets for many variables vary by site based on varying expectations for environmental outcomes (details are provided in Appendix A). Several of the Horizons One Plan targets consider only sampling occasions associated with specified dates or flows (Table 2). This reflects considerations associated with the effects of the contaminant. For example, nutrients and microbial contaminants are of less concern during high flows. The bathing water microbial concentration targets (*E. coli* (Bathing); Table 2) only apply to the summer season when swimming is likely. These additional details for how the threshold values are compared to observations are provided for each variable in Table 2.

Criteria for discharge sites are based on the change in state between an associated downstream impact site and an upstream SoE site. Appendix B provides a list of the point source discharges and their associated upstream (SoE) and downstream (impact) monitoring sites.

For sites where there was no appropriate flow data available, but where the targets are based on sampling occasions associated with a flow constraint, targets were evaluated against *all* available data; sites for which this has been done are highlighted in the results.

Table 2: Details of the Horizons One Plan targets for each water quality variable used to grade the state of the river, discharge, lake, estuary and coastal sites.

	Target name	**Compliance statistic[1]**	**Flow constraint[2]**	**Target description**
River	Chlorophyll-a	Maximum	100	The algal biomass on the river bed must not exceed […] milligrams of chlorophyll-*a* per square metre.
	Clarity	Minimum	50	The visual clarity of the water^ measured as the horizontal sighting range of a black disc must equal or exceed […] metres when the river^ is at or below the 50^{th} flow exceedance percentile..
	DO (Sat)	Minimum	100	The Dissolved oxygen (DO) must exceed […][3]% of saturation.
	DRP	Mean	80	The annual average concentration of dissolved reactive phosphorus (DRP) when the river flow is at or below the 20^{th} flow exceedance percentile must not exceed […] grams per cubic metre, unless natural levels already exceed this.
	E. coli (Bathing)	Maximum	50	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres between 1 November - 30 April (inclusive) when the river^ flow is at or below the 50^{th} flow exceedance percentile*.
	E. coli (year round)	Maximum	80	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres year-round when the river^ flow is at or below the 20^{th} flow exceedance percentile*.
	MCI	Minimum	100	The Macroinvertebrate Community Index (MCI) must exceed […][4].
	NH4-N (max)	Maximum	100	The maximum concentration of ammoniacal-N must not exceed […] grams per cubic metre.
	NH4-N (mean)	Mean	100	The average concentration of ammoniacal-N must not exceed […] grams per cubic metre.
	Periphyton (filaments)	Maximum	100	The maximum cover of the visible river bed by periphyton as filamentous algae more than 2 centimetres long must not exceed […]%.
	Periphyton (mats)	Maximum	100	The maximum cover of visible river bed by periphyton as diatoms or cyanobacteria more than 0.3 centimetres thick must not exceed […]%.

	Target name	Compliance statistic[1]	Flow constraint[2]	Target description
	POM	Mean	50	The average concentration of particulate organic matter when the river flow is at or below 50th flow exceedance percentile must not exceed […] grams per cubic meter.
	sCBOD5	Maximum	80	The monthly average five-days filtered / soluble carbonaceous biochemical oxygen demand (sCBOD5) when the river^ flow is at or below the 20th flow exceedance percentile must not exceed […] grams per cubic metre.
	SIN	Maximum	80	The annual average concentration of soluble inorganic nitrogen (SIN) when the river flow is at or below the 20th flow exceedance percentile must not exceed […] grams per cubic metre, unless natural levels already exceed this.
Discharge	pH (change)	abs(Maximum)	100	The pH of the water must not be changed by more than […].
Discharge	Temperature (change)	abs(Maximum)	100	The temperature of the water must not be changed by more than […] degrees Celsius.
Discharge	Clarity (change)	Maximum	100	The visual clarity of the water measured as the horizontal sighting range of a black disc must not be reduced by more than […] %.
Discharge	QMCI (change)	Maximum	100	There must be no more than a 20% reduction in Quantitative Macroinvertebrate Community Index (QMCI) score between appropriately matched habitats upstream and downstream of discharges to water.
Lake	Chlorophyll-a (mean)	Mean	NA	The annual average algal biomass must not exceed […] milligrams chlorophyll a per cubic metre.
Lake	Chlorophyll-a (max)	Maximum	NA	Samples must not exceed […] milligrams chlorophyll a per cubic metre.
Lake	Clarity	Minimum	NA	The visual clarity of the water^ measured as the horizontal sighting range of a black disc must equal or exceed […] metres.
Lake	E. coli (Bathing)	Maximum	NA	The concentration of Escherichia coli must not exceed […] per 100 millilitres 1 November - 30 April (inclusive).
Lake	E. coli (non-bathing)	Maximum	NA	The concentration of Escherichia coli must not exceed […] per 100 millilitres 1 May - 31 October (inclusive).
Lake	NH4-N (ph>8.5)	Maximum	NA	The concentration of ammoniacal nitrogen must not exceed […] grams per cubic metre when lake pH exceeds 8.5 within the epilimnion (shallow lakes) or within 2m of the water^ surface (deep lakes).
Lake	TN	Mean	NA	The annual average concentration of total nitrogen must not exceed […]grams per cubic metre.
Lake	TP	Mean	NA	The annual average concentration of total phosphorus (TP) must not exceed […] grams per cubic metre.
Coastal	Chlorophyll-a	Mean	NA	The annual average algal biomass must not exceed […] milligrams of chlorophyll a per cubic metre.
Coastal	Enterococci (bathing)	Maximum	NA	The concentration of enterococci must not exceed […] per 100 millilitres 1 November - 30 April (inclusive).

	Target name	Compliance statistic[1]	Flow constraint[2]	Target description
	Enterococci (non-bathing)	Maximum	NA	The concentration of enterococci must not exceed […] per 100 millilitres 1 May - 31 October (inclusive).
	Faecal Coliforms (median)	Median	NA	The median concentration of faecal coliforms must not exceed […] per 100 millilitres.
	Faecal Coliforms (q90)	90th	NA	The 90th percentile concentration of faecal coliforms must not exceed […] per 100 millilitres.
	NH4-N	Mean	NA	The average concentration of ammoniacal nitrogen must not exceed […] grams per cubic metre.
	TN	Mean	NA	The annual average concentration of total nitrogen must not exceed […]grams per cubic metre.
	TP	Mean	NA	The annual average concentration of total phosphorus (TP) must not exceed […] grams per cubic metre.
Estuary	Chlorophyll-a	Mean	100	The annual average algal biomass must not exceed […] milligrams of chlorophyll a per cubic metre.
	Clarity	Minimum	50	The visual clarity of the water^ measured as the horizontal sighting range of a black disc must equal or exceed […] metres when the river^ is at or below the 50th flow exceedance percentile..
	DO (Sat)	Minimum	100	The concentration of dissolved oxygen must exceed […] % of saturation.
	DRP	Mean	80	The annual average concentration of dissolved reactive phosphorus (DRP) when the river^ flow is at or below the 20th flow exceedance percentile* must not exceed […] grams per cubic metre.
	E. coli (Bathing)	Maximum	50	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres between 1 November - 30 April (inclusive) when the river^ flow is at or below the 50th flow exceedance percentile*.
	E. coli (year round)	Maximum	80	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres year-round when the river^ flow is at or below the 20th flow exceedance percentile*.
	NH4-N	Mean	100	The average concentration of ammoniacal-N must not exceed […] grams per cubic metre.
	SIN	Mean	80	The annual average concentration of soluble inorganic nitrogen (SIN) when the river flow is at or below the 20th flow exceedance percentile must not exceed […] grams per cubic metre, unless natural levels already exceed this.
	Temperature	Maximum	100	The temperature of the water^ must not exceed […] degrees Celsius.

1. Where all observations must comply with the target, the compliance statistic is either "Minimum" or "Maximum". Where a statistic of the observation's distribution must comply, the compliance statistic is shown as "Mean" or "Median" percentile (i.e. 80, 90 or 95).
2. The maximum flow percentile for an observation to be included in the analysis.
3. The symbol […] indicates that the thresholds used were variable and site specific. The thresholds for all sites are provided in Appendix A.
4. Unless natural physical conditions are beyond the scope of application of the MCI. In cases where the river^ habitat is suitable for the application of the soft-bottomed variant of the MCI (sb-MCI) the Water Quality

3.1.2 Handling censored values

Censored values were replaced by imputation for the purposes of calculating the compliance statistics. Left censored values (values below the detection limit(s)) were replaced with imputed values generated using ROS (Regression on Order Statistics; Helsel, 2012) following the procedure described in Larned *et al.* (2015). The ROS procedure produces estimated values for the censored data that are consistent with the distribution of the uncensored values and can accommodate multiple censoring limits. When there are insufficient non-censored data to evaluate a distribution from which to estimate values for the censored observations, censored values are replaced with half of their reported value.

Censored values above the detection limit were replaced with values estimated using a procedure based on survival analysis (Helsel, 2012). A parametric distribution is fitted to the uncensored observations and then values for the censored observations are estimated by randomly sampling values larger than the censored values from the distribution. The survival analysis requires a minimum number of observations for the distribution to be fitted; hence in the case that there were fewer than 24 observations, censored values above the detection limit were replaced with 1.1* the detection limit. The supplementary file outputs provide details about whether and how imputation was conducted for each site by target assessment.

3.1.3 Time period for assessments

When grading sites based on water quality targets, it is general practice to define consistent time periods for all sites and to define the acceptable proportion of missing observations (i.e., data gaps) and how these are distributed across sample intervals so that site grades are assessed from reasonably comparable data. The time period, acceptable proportion of gaps and representation of sample intervals by observations within the time period are commonly referred to as site inclusion or filtering rules (e.g., Larned et al., 2018).

The current state grading assessments were made for the 5-year time period to end of June 2022. Additionally, rolling state grading assessments for 5-year period windows between July and June were performed over the full length of the records. This involved starting with the first 5-year window of the record, evaluating the state, then shifting the 5-year window incrementally by 1-year and re-evaluating state until the end of the record (which aligns with the current state assessment).

State was assessed based on 5 years of observations because the statistical precision of the compliance statistics depends on the variability of the water quality observations and the number of observations. For a given level of variability, the precision of a compliance statistic increases with the number of observations. This is particularly important for sites that are close to a threshold defined by an attribute band because the confidence that the assessment of state is 'correct' (i.e., that the site has been correctly graded) increases with the precision of the compliance statistics (and therefore with the number of observations). As a general rule, the rate of increase in the precision of compliance statistics decreases for sample sizes greater than 30 (i.e., there are diminishing returns on increasing sample size with respect to precision (and therefore confidence in the assigned grade) above this number of observations; McBride, 2005). In this study, a period of five years represented a reasonable trade-off for most of the attributes because it yielded a sample size of 30 or more observations for many sites and attribute combinations.

Grades at sites that had at least 30 observations (or 5 for annually monitored variables) are given a grade status of "final". In addition, "interim" results are provided for sites with at least 10 observations (monthly monitoring) or 3 observations (annual monitoring). Site grades which do not meet the final or interim inclusion criteria are not presented in this report but are available in the supplementary materials.

3.2 Trend analysis

3.2.1 Sampling dates, seasons and time periods for analyses

In trend assessments, there are several reasons why it is important to define the trend period and seasons and to assess whether the observations are adequately distributed over time. First, because variation in many water quality variables is associated with the time of the year or "season", the robustness of trend assessment is likely to be diminished if the observations are biased to certain times of the year. Second, a trend assessment will always represent a time period; essentially that defined by the first and last observations. The assessment's characterisation of the change in the observations over the time period will not be robust if the observations are not reasonably evenly distributed across the time period. For these reasons, important steps in the data compilation process include specifying the seasons, the time period, and ensuring adequately distributed data.

Monitoring programs are generally designed to sample with a set frequency, (e.g., monthly, quarterly). The trend analysis 'season' is generally specified to match this sampling frequency (e.g., seasons are months, or quarters). There is therefore generally an observation for each sample interval (i.e., each season, such as month or quarter, within each year). Sampling frequency for some variables is annually. For example, annual sampling is common for biological sampling such as macro-invertebrates. In this case the 'season' is specified by the year.

Two common deviations from the prescribed sampling regime are (1) the collection of more than one observation in a sample interval (e.g., two observations within a month) and (2) a change in sampling interval within the time period. For type (1) deviations, the median within each sample interval was used. For type (2) deviations, the sampling interval was coarsened to define seasons for the part of the record with the higher sampling frequency. This was achieved by taking the observation in the higher frequency part of the record that was closest to the midpoint of the seasons defined by the coarser part of the record. The reason for not using the median value in this case is that it will induce a trend in variance, which will invalidate the distributional assumptions of the Mann Kendall S test statistic (Helsel et al., 2020).

River dissolved oxygen data was provided as a time series of daily minima for some sites. For the trend assessments, this data is coarsened to a monthly sampling interval. This was done by taking the observation associated with the mid-point of the month. The coarsening of the dissolved oxygen time series was considered necessary for two reasons. Firstly, for water quality variables as sampling frequencies increase, the autocorrelation between observations generally increases. Autocorrelation of samples violates the assumption of the Mann Kendall test that samples are independent (see section 3.2.4). Secondly, to allow robust comparison of trends between sites and variables at the regional level, it is useful to have similar levels of statistical power between assessments, and therefore to have similar numbers of samples for each trend period.

The trend for all site and variable combinations was characterised by the rate of change of the central tendency of the observations through time. Because water quality is constantly varying through time, the evaluated rate of change depends on the time-period over which it is assessed (e.g., Ballantine *et al.*, 2010; Larned *et al.*, 2016). Therefore, trend assessments are specific for a given period of analysis. HRC requested that trend periods of 10, 20 and 30 years, ending on 30 June 2022, be evaluated.

For a regional study that aims to allow robust comparison of trends between sites and to provide a synoptic assessment of trends across a whole region, such as the present study, it is important that the trends evaluated at each site are commensurate in terms of their statistical power and representativeness of the time period. In these types of studies, it is general practice to define consistent time periods (i.e., trend duration and start date) so that all sites are subjected to the same conditions (i.e., equivalent political, climate, economic conditions). It is also general practice to define the acceptable proportion of gaps and how these are distributed across sample intervals so that the reported trends are assessed from comparable data. The acceptable proportion of gaps and representation of sample intervals by observations within the time period are commonly referred to as site inclusion or filtering rules (e.g., Larned *et al.*, 2018) but this is also termed ‘site screening criteria’ and ‘completeness criteria’.

There are no specific data requirements or filtering rules for trend assessments performed over many sites and variables such as the present study. The definition of filtering rules is complicated by a trade-off: more restrictive rules increase the robustness of the individual trend analyses but will generally exclude a larger number of sites thereby reducing spatial coverage. In general, this trade-off is also affected by the duration of trend period. Steadily increasing monitoring effort over time means that shorter and more recent trend periods will generally have a larger number of eligible sites.

The application of filtering rules for variables that are measured at quarterly intervals or more frequently requires two steps. First, retain sites for which observations are available for at least *X*% of the years in the time period. Second, retain sites for which observations are available for at least *Y*% of the sample intervals. For variables that are measured annually such as MCI, the filtering rules are applied by retaining sites for which values are available for at least *X*% of the years in the trend period.

In this study, filtering rules applied by Larned et al. (2019) were used, which set X and Y to 80%. Further, the definition of seasons was flexible for lakes, estuaries and coastal sites in order to maximise the number of sites that were included. If the site failed to comply with filter rule (2) when seasons were set as months, a coarsening of the data to quarterly seasons was applied and the filter rule (2) was reassessed. If the data then complied with filter rule (2), the trend results based on the coarser (i.e., quarterly) seasons were retained for reporting. It is noted that the filtering rules for imply a tolerance of variable levels of statistical power and temporal representativeness across the sites that were included in the analysis.

3.2.2 Handling censored values

For several water-quality variables, true values are occasionally too low or too high to be measured with precision. These measurements are called censored values. The “detection limit” is the lowest value that can be measured by an analytical method (either a laboratory measurement or a measurement made in the field) and the “reporting limit” is the greatest value of a variable that can be measured. Water-quality datasets from New Zealand rivers and lakes often include DRP, TP and NH4N measurements that are censored because they are below detection limits, and ECOLI and CLAR measurements that are censored because they are above reporting limits.

Censored values are managed in a special way by the non-parametric trend assessment methods described in section 3.2.4. It is therefore important that censored values are correctly identified in the data. Detection limits or reporting limits that have changed through the trend time period (often due to analytical changes) can induce trends that are associated with the changing precision of the measurements rather than actual changes in the variable. This possibility needs to be accounted for in the trend analysis and this is another reason that it is important that censored values are correctly identified in the data.

A “high-censor” filter was applied in the trend assessments to minimise biases that might be introduced due to changes in detection limits through the trend assessment period. The high-censor filter identifies the highest detection limit for each water quality variable in the trend assessment period (or some nominated highest detection limit) and replaces all observations below this level with the highest detection limit and identifies these as censored values.

The water quality datasets included a small number of left censored values that were much larger than the apparent detection limit at any given time (outliers). Unsupervised application of the high-censor filter in these circumstances can lead to the unnecessary loss of statistical power in the assessment. To avoid this problem, the following approach was employed. It was expected that systematic changes in detection limit would be relatively consistent for a variable across a monitoring domain (i.e., lakes, rivers, coastal). To explore patterns in detection level, left censored data was plotted over time by variable and domain and used these plots to identify the occurrence of outliers. A maximum realistic detection level was identified for each variable and domain (e.g., rivers, lakes, coastal, estuary) and the high-censor level was capped at these values.

3.2.3 Seasonality assessment

For many site/variable combinations, observations vary systematically by season (e.g., by month or quarter). In cases where seasons are a major source in variability, accounting for the systematic seasonal variation should increase the statistical power of the trend assessment (i.e., increase the confidence in the estimate of direction and rate of the trend). The purpose of a seasonality assessment is to identify whether seasons explain variation in the water quality variable. If this is true, then it is appropriate to use the seasonal versions of the trend assessment procedures at the trend assessment step (Section 3.2.4).

Seasonality was evaluated using the Kruskall-Wallis multi-sample test for identical populations. This is a non-parametric ANOVA that determines the extent to which season explains variation in the water quality observations. Following Hirsch *et al*. (1982), site/variable combinations were identified as being seasonal based on the *p*-value from the Kruskall-Wallis test with $\alpha=0.05$. For these sites/variable combinations, subsequent trend assessments followed the “seasonal” variants, described in section 3.2.4.

The choice of α is subjective and a value of 0.05 is associated with a very high level of certainty (95%) that the data exhibit a seasonal pattern. In our experience there are generally diminishing differences between the seasonal and non-seasonal trend assessments for seasonality test *p*-values values larger than 0.05 (Helsel *et al*., 2020).

3.2.4 Analysis of trends

The purpose of trend assessment is to evaluate the direction (i.e., increasing or decreasing) and rate of the change in the central tendency of the observed water quality values over the period of analysis (i.e., the trend). Because the observations represent samples of the water quality over the period of analysis, there is uncertainty about the conclusions drawn from their analysis. Therefore, statistical models are used to determine the direction and rate of the trend and to evaluate the uncertainty of these determinations.

Trends were evaluated using the LWPTrends functions (Snelder & Fraser, 2021) that are implemented in the R statistical computing software (R Core Team, 2023). A brief description of the theoretical basis for these functions is described below.

3.2.4.1 Trend direction assessment

The trend direction and the confidence in the trend direction were evaluated using either the Mann Kendall assessment or the Seasonal Kendall assessment. Although the non-parametric Sen slope regression also provides information about trend direction and its confidence, the Mann Kendall assessment is recommended, rather than Sen slope regression, because the former more robustly handles censored values. However, Sen slope regression is the recommended method for assessing the trend rate (see Section 3.2.4.2).

The Mann Kendall assessment requires no *a priori* assumptions about the distribution of the data but does require that the observations are randomly sampled and independent (no serial correlation) and that there is a sample size of ≥ 8. Both the Mann Kendall and Seasonal Kendall assessments are based on calculating the Kendall *S* statistic, which is explained diagrammatically in Figure 3.

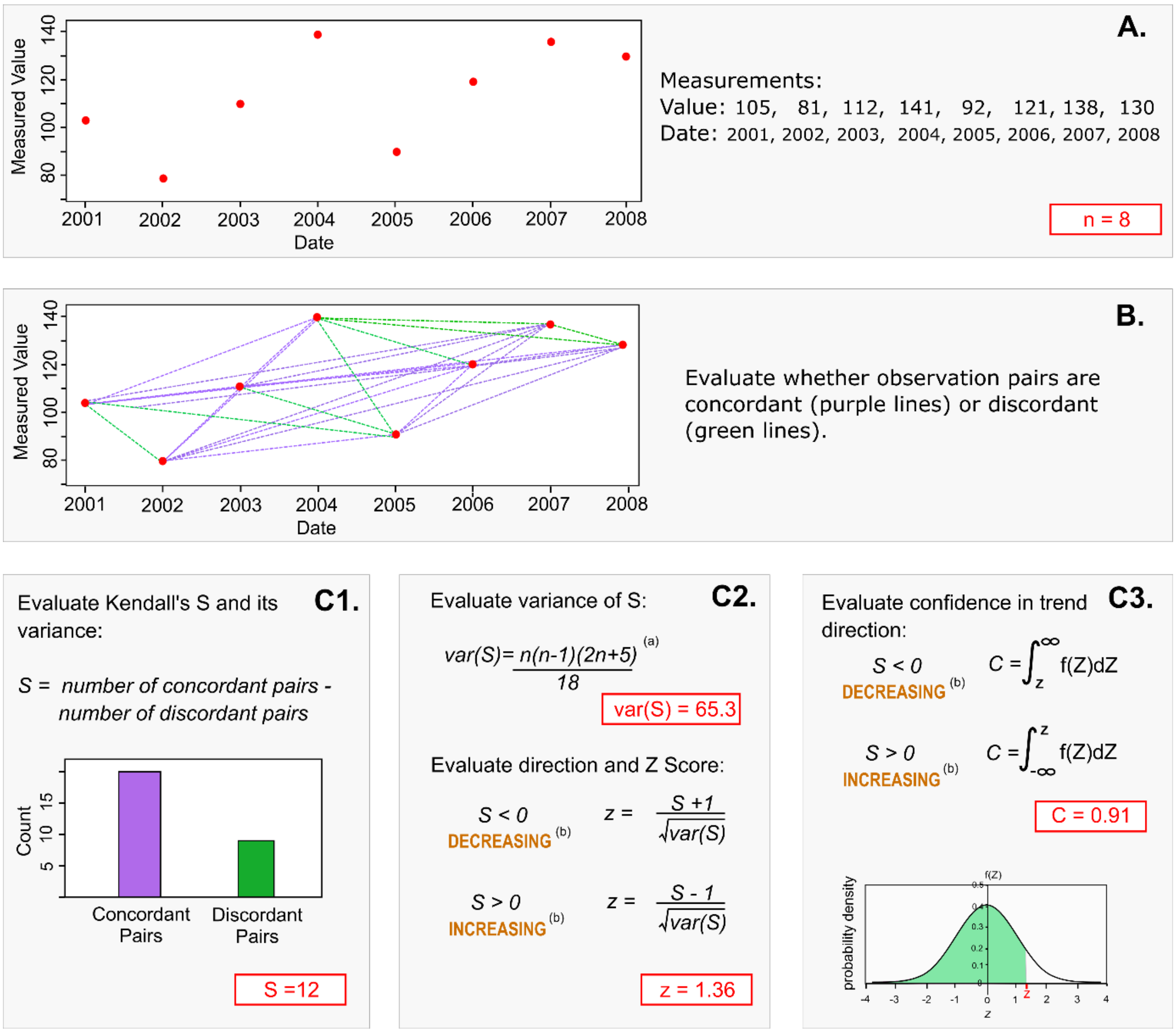

Figure 3. Pictogram of the steps taken in the trend direction assessment to calculate the Kendall S statistic and confidence in trend direction. Notes: [a] the calculation of the

variance in S has some adjustments to account for ties (numerically equal values) and censored values. Details of these adjustments can be found in (Helsel 2005, 2012). [b] There is a third alternative, where S=0. In this case C is 0.5, and the trend direction is classified as "indeterminate". Values of S equal to -1 or 1 will also result in a Z value of 0, a p-value of 1 and a C value of 0.5 and the trend direction is similarly classified as "indeterminate".

The Kendall *S* statistic is calculated by first evaluating the differences between all pairs of water quality observations (Figure 3, A and B). Positive differences are termed 'concordant' (i.e., the observations increase with increasing time) and negative differences are termed 'discordant' (i.e., the observations decrease with increasing time). The Kendall *S* statistic is the number of concordant pairs minus the number of discordant pairs (Figure 3, C1). The water quality trend direction is indicated by the sign of *S* with a positive or negative sign indicating an increasing or decreasing trend, respectively (Figure 3, C2).

The seasonal version of the Kendall *S* statistic *S* is calculated in two steps. First, for each season, the *S* statistic is calculated in the same manner as shown in Figure 3 but for data pertaining to observations in each individual season. Second, *S* is the sum of values over all seasons ($S = \sum_1^n S_i$), where S_i is the number of concordant pairs minus the number of discordant pairs in the i^{th} season and n is the number of seasons. The variance of *S* is calculated for each season and then summed over all seasons.

The sign (i.e., + or -) of the *S* statistic calculated from the sample represents the best estimate of the population trend direction but is uncertain (i.e., the direction of the population trend cannot be known with certainty). A continuous measure of confidence in the assessed trend direction can be determined based on the posterior probability distribution of S, the true (i.e., population) difference in concordant and discordant pairs (Snelder et al., 2022). The posterior probability distribution of *S* is given by a normal distribution with mean of *S* and variance of *var(S)*. The confidence in assessed trend direction can be evaluated as the proportion of the posterior probability distribution that has the same sign as S.

In practice, confidence can be calculated by first transforming the value of $S = 0$ on the posterior probability distribution into a standard normal deviate, Z (panel C2). *C* is then calculated as area under the standard normal distribution to the left (Z>0) or right (Z<0) of the value of Z, using the quantile function for the normal distribution.

The value C can be interpreted as the probability that the sign of the calculated value of *S* indicates the direction of the population trend (i.e., that the calculated trend direction is correct). The value C ranges between 0.5, indicating the sign of *S* is equally likely to be in the opposite direction to that indicated by the true trend, to 1, indicating complete confidence that the sign of *S* is the same as the true trend.

As the size of the sample (i.e., the number of observations) increases, confidence in the trend direction increases. When the sample size is very large, C can be high, even if the trend rate is very low. It is important therefore that C is interpreted correctly as the confidence in direction and not as the importance of the trend. As stated at the beginning of this section; both trend direction and the trend rate are relevant and important aspects of a trend assessment.

3.2.4.2 Assessment of trend rate

The method used to assess trend rate is based on non-parametric Sen slope regressions of water quality observations against time. The Sen slope estimator (SSE; Hirsch *et al.,* 1982) is the slope parameter of a non-parametric regression. SSE is calculated as the median of all possible inter-observation slopes (i.e., the difference in the measured observations divided by the time between sample dates; Figure 4).

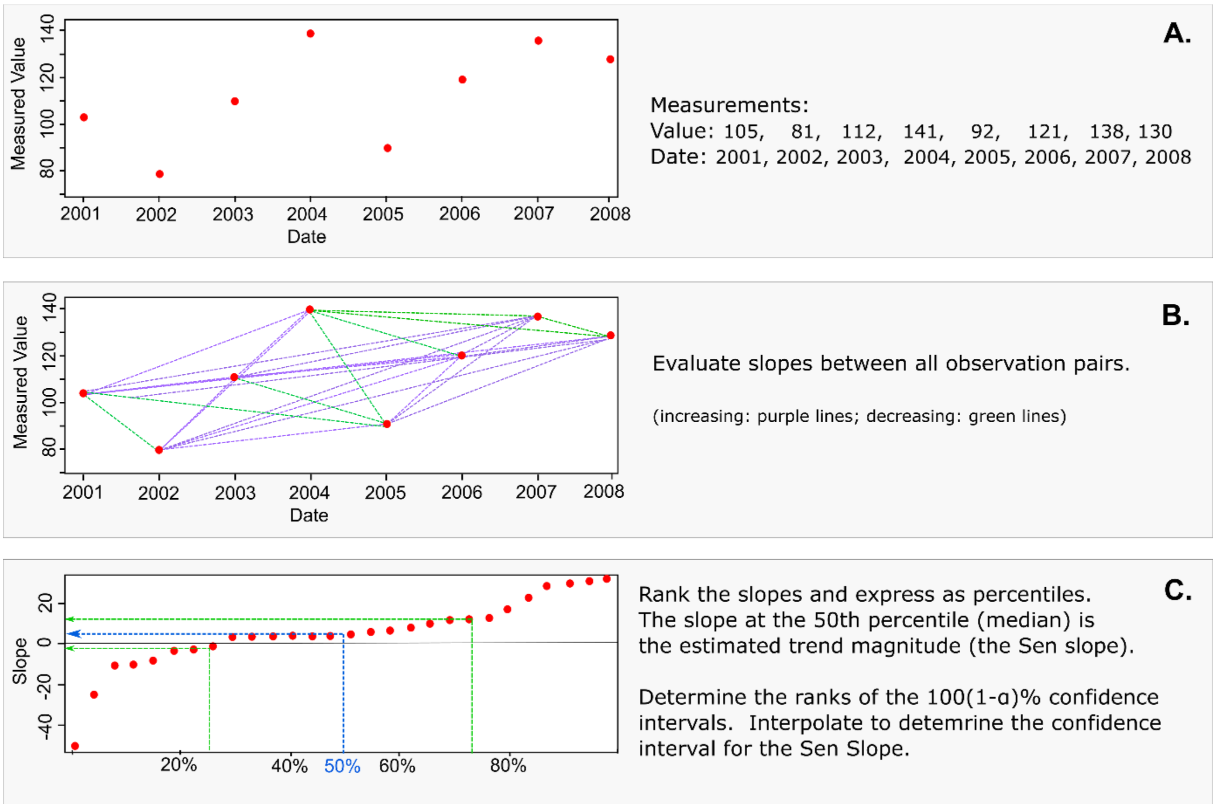

Figure 4. Pictogram of the calculation of the Sen slope, which is used to characterise trend rate.

The seasonal Sen slope estimator (SSSE) is calculated in two steps. First, for each season, the median of all possible inter-observation slopes is calculated in same manner as shown in Figure 4 but for data pertaining to observations in each individual season. Second, *SSSE* is the median of the seasonal values.

Uncertainty in the assessed trend rate is evaluated following a methodology outlined in Helsel and Hirsch (2002). To calculate the 100(1-α)% two-sided symmetrical confidence interval about the fitted slope parameter, the ranks of the upper and lower confidence limits are determined, and the slopes associated with these observations are applied as the confidence intervals.

The inter-observation slope cannot be definitively calculated between any combination of observations in which either one or both observations comprise censored values. Therefore, it is usual to remove the censor sign from the reported laboratory value and use just the 'raw' numeric component (i.e., <1 becomes 1) multiplied by a factor (such as 0.5 for left-censored and 1.1 for right-censored values). This ensures that in the Sen slope calculations, any left-censored observations are always treated as values that are less than their 'raw' values and right censored observations are always treated as values that are greater than their 'raw' values. The inter-observation slopes associated with the censored values are therefore imprecise (because they are calculated from the replacements). However, because the Sen slope is the median of all the inter-observation slopes, the Sen slope is unlikely to be affected by censoring when a small proportion of observations are censored. As the proportion of censored values increase, the probability that the Sen slope is affected by censoring increases. The outputs from the trend assessment provide an 'analysis note' to identify Sen Slopes where one or both of the observations associated with the median inter-observation slope is censored.

3.2.5 Interpretation of trends

The trend assessment procedure used here facilitates a more nuanced inference than the 'yes/no' output corresponding to the chosen acceptable misclassification error rate. The confidence in direction (C) can be transformed into a continuous scale of confidence the trend was decreasing (C_d). For all trends with $S < 0$, $C_d = C$, and for all $S > 0$ a transformation is applied so that $C_d = 1\text{-}C$. C_d ranges from 0 to 1.0. When C_d is very small, a decreasing trend is highly unlikely, which because the outcomes are binary, is the same as an increasing trend is highly likely.

The categorisation of confidence in trend direction used by LAWA was used to present the results. Each site trend was assigned to a category by firstly, converting C_d into a confidence that a trend was improving (C_i). Improvement is indicated by decreasing trends for all the water quality variables in this study ($C_i = C_d$) except for the macroinvertebrate metrics, visual clarity, Secchi depth and dissolved oxygen (for which increasing trends indicate improvement). For these variables, C_i is the complement of C_d (i.e., C_i=1-C_d). Secondly, each site/variable combination was assigned to a confidence in trend direction category according to its evaluated confidence of improvement and the categories shown in Table 3.

Table 3. Level of confidence categories used to convey trend confidence and direction.

Categorical level of trend confidence and direction	Value of C_i (%)
Very likely improving	0.90–1.00
Likely improving	0.67–0.90
Low confidence in direction	0.33–0.67
Likely degrading	0.10–0.33
Very likely degrading	0.0–0.10

The aggregate proportion of sites in each category shown in Table 3 were calculated for sites and for each variable and these values were plotted as colour coded bar charts. These charts provide a graphical representation of the proportions of improving and degrading trends at the levels of confidence indicated by the categories. As improvement cannot be clearly associated with a particular direction of pH, it has been excluded from results reported based on improvement/degradation. However, results for trends in pH are provided in the supplementary material.

For variables with high levels of censoring, it is possible to obtain results that indicate high confidence in trend direction but have a Sen slope of zero. This occurs due to the censored values being treated as ties in the analysis. The correct interpretation of the zero Sen slope is that it is a rate of change that is below the rate of detection given by the detection limit and time period. To highlight the occurrence of zero Sen slopes, mapped and tabulated site results for categorical levels of trend confidence and direction also include information to indicate where Sen Slopes were evaluated to be zero.

Outputs from the trend analyses were also classified into four direction categories: improving, degrading, indeterminate, and not analysed. An increasing or decreasing trend category was assigned based on the sign of the S statistic from the Mann Kendall test. An indeterminate trend category was assigned when the Z score equalled zero. Trends were classified as "not analysed" for two reasons:

1) When a large proportion of the values were censored (data has <5 non-censored values and/or <3 unique non-censored values). This arises because trend analysis is based on examining differences in the value of the variable under consideration between all pairs of sample occasions. When a value is censored, it cannot be compared with any other value and the comparison is treated as a "tie" (i.e., there is no change in the variable between the two sample occasions). When there are many ties there is little information content in the data and a meaningful statistic cannot be calculated.

2) When there is no, or very little, variation in the data because this also results in ties. This can occur because laboratory analysis of some variables has low precision (i.e., values have few or no significant figures). In this case, many samples have the same value, and this then results in ties.

4 Results for state assessments

4.1 Rivers

4.1.1 Grading of SoE sites

The results for grading the river SoE sites according to targets described in section 3.1.1 are mapped in Figure 5 and shown as colour coded tables in Figure 6 (Manawatū FMU) and Figure 7 (all other FMUs). Plots of rolling state grades for sites, (by target) are provided in Appendix C1.

The cells marked with circles rather than filled cells shown in Figure 6 and Figure 7 indicate that there were insufficient observations to make statistically robust assessments of state (see Section 3.1.1). This occurred more often for variables whose targets included specified flow states, for example clarity, *E. coli*, DRP, and SIN (Table 2) or for those that were monitored annually (e.g., MCI).

More than 75% of sites failed the Horizons One Plan targets for DRP, MCI, *E. coli* and Clarity. Conversely, more than 75% of sites passed the targets for NH_4-N, periphyton (mats) and DO (Sat). Grades varied across the region for chlorophyll-*a*, POM, periphyton (filaments) and SIN.

Figure 5: Maps showing SoE site state grades based on the Horizons One Plan criteria. Grades that are defined as "final" are shown with circles, and "interim" grades are shown with triangles. Smaller sized shapes indicate that the criteria had a flow constraint and there was no flow available at the site.

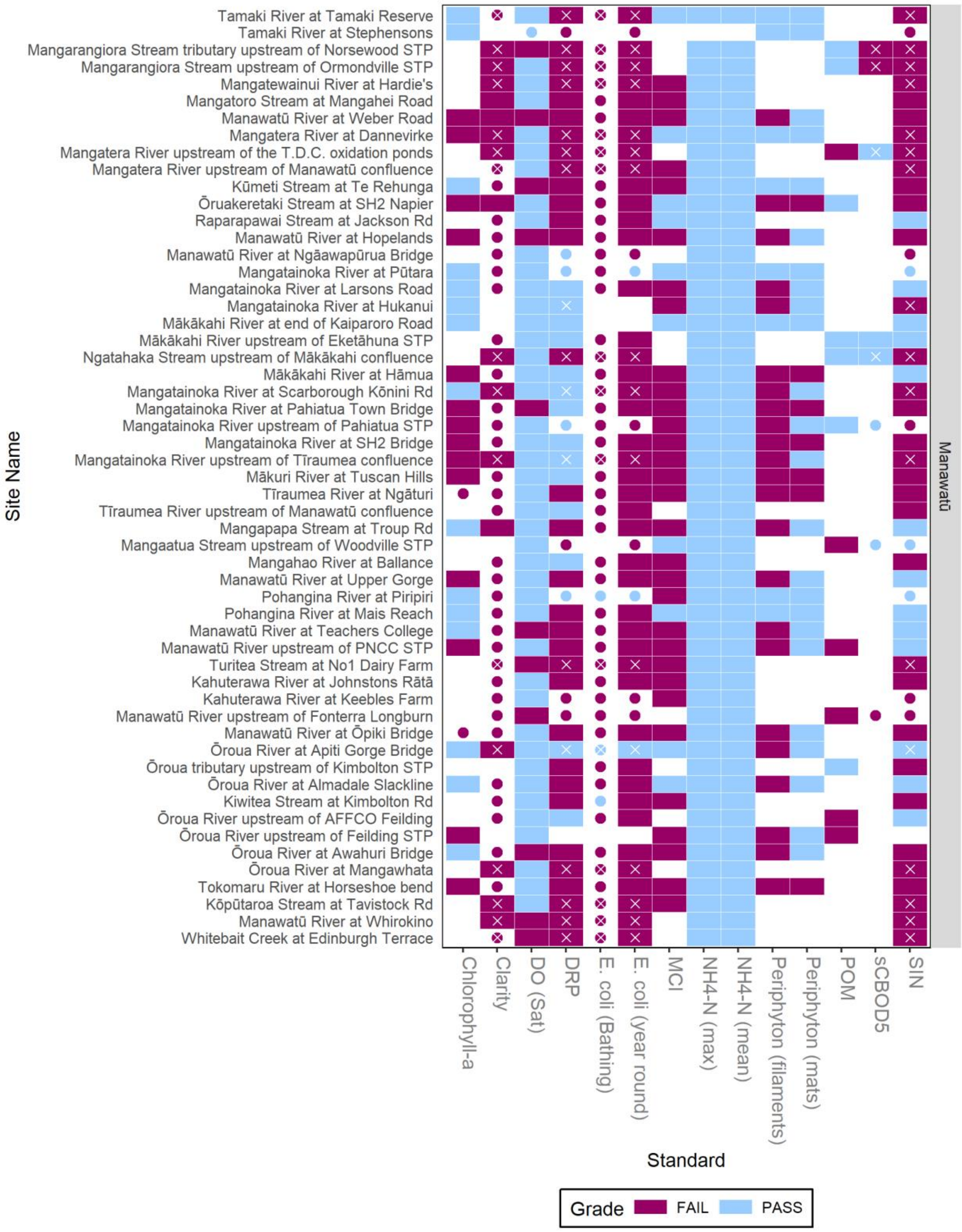

Figure 6: Assessed state for SoE river monitoring sites in the Manawatū catchment. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

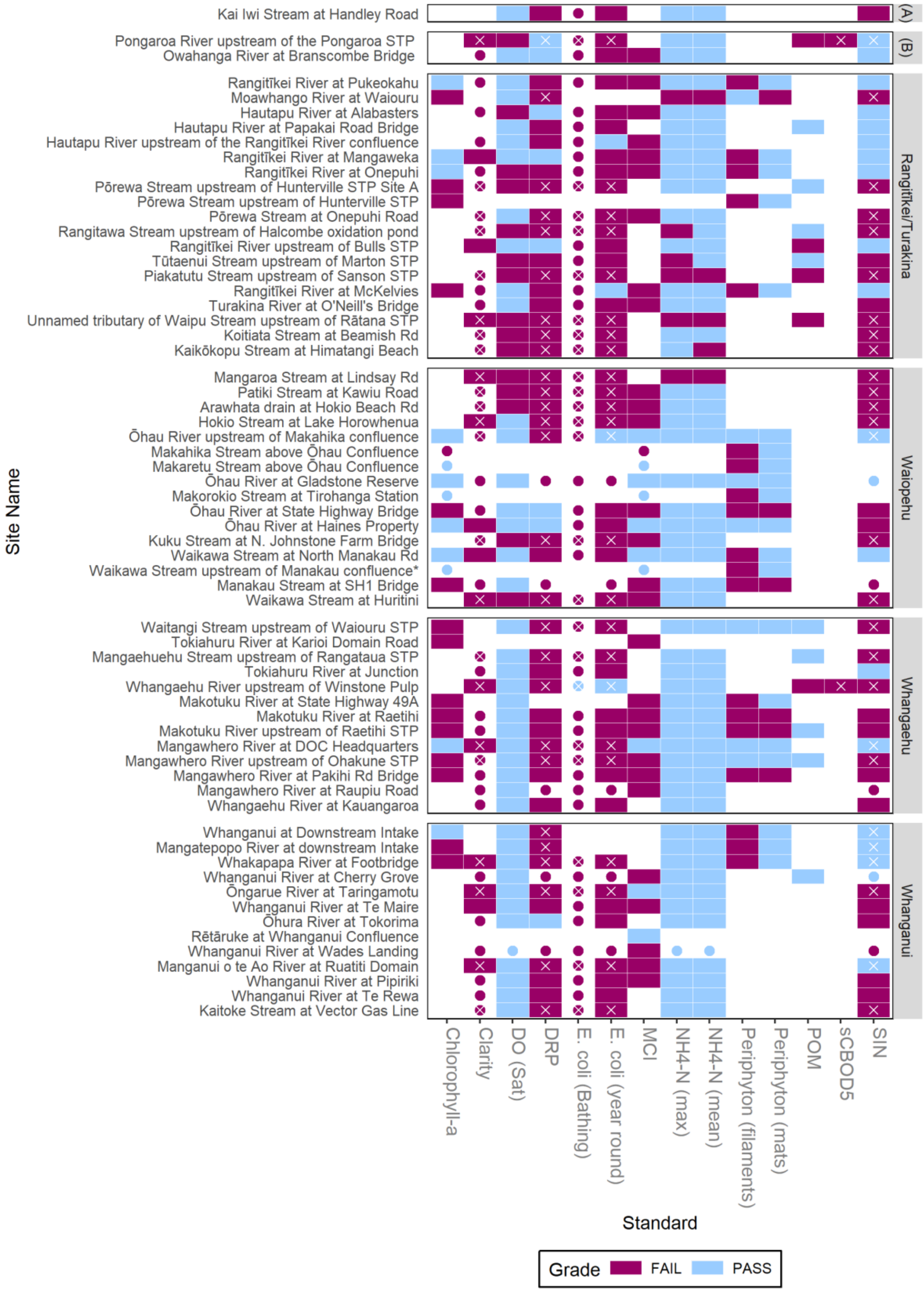

Figure 7: Assessed state for SoE river monitoring sites outside of the Manawatū catchment. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

4.1.2 Grading of Impact sites

The results for grading the river impact sites according to targets described in section 3.1.1 are mapped in Figure 8 and shown as colour coded tables in Figure 9. Plots of rolling state grades for sites, (by target) are provided in Appendix C2.

More than 75% of sites failed the Horizons One Plan criteria for chlorophyll-*a*, periphyton (filaments), DRP, SIN, MCI, *E. coli* and Clarity. Conversely, more than 75% of sites passed the criteria for NH_4-N and periphyton (mats). Grades varied across the region for POM. These patterns are similar to those of the SoE sites, although with a tendency for greater proportions of failing sites.

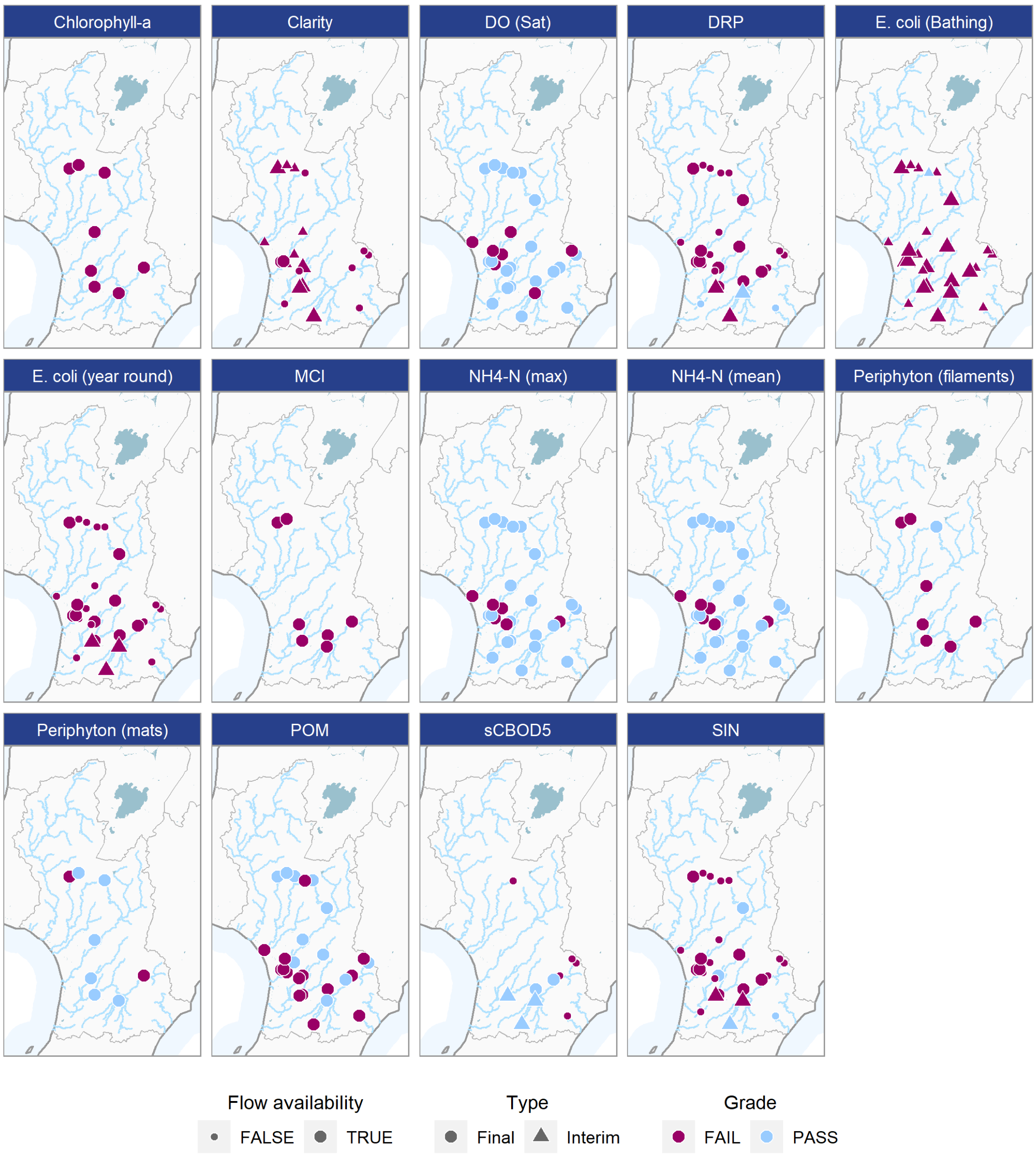

Figure 8: Maps showing impact site state grades based on the Horizons One Plan criteria. Grades that are defined as "final" are shown with circles, and "interim" grades are shown with triangles. Smaller sized shapes indicate that the criteria had a flow constraint and there was no flow available at the site.

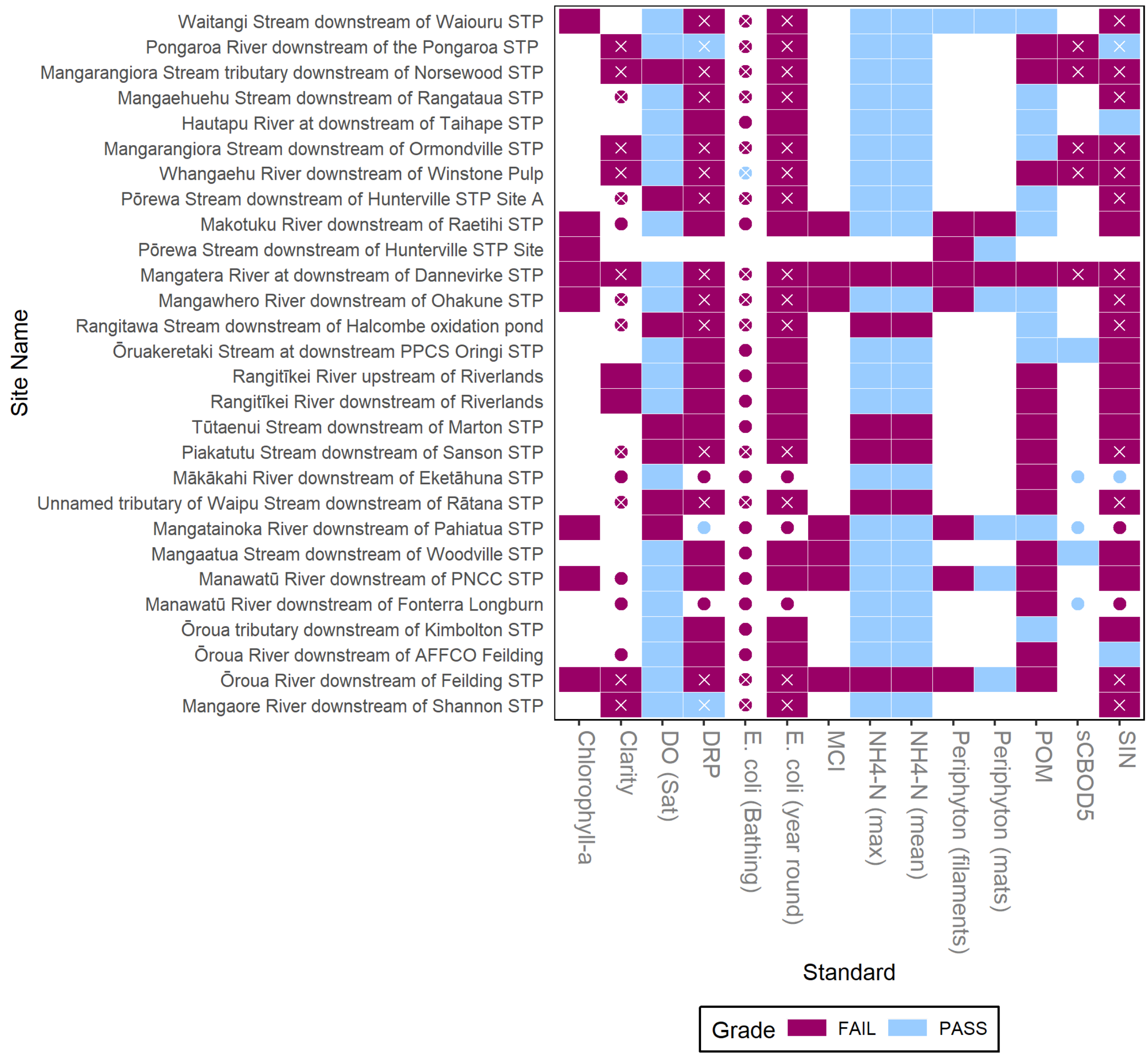

Figure 9: Assessed state for impact river monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

4.1.3 Grading of discharge sites

The results of grading the discharge sites according to the Horizons One Plan water quality variable change targets are mapped in Figure 10 and shown in Figure 10. Most sites failed the criteria for pH, and Clarity. There were very few sites with QMCI data to allow evaluation of the criteria; of the 6 sites, 50% received a pass grade. Grades varied across the region for the temperature criteria but were slightly dominated by sites meeting the targets (73%).

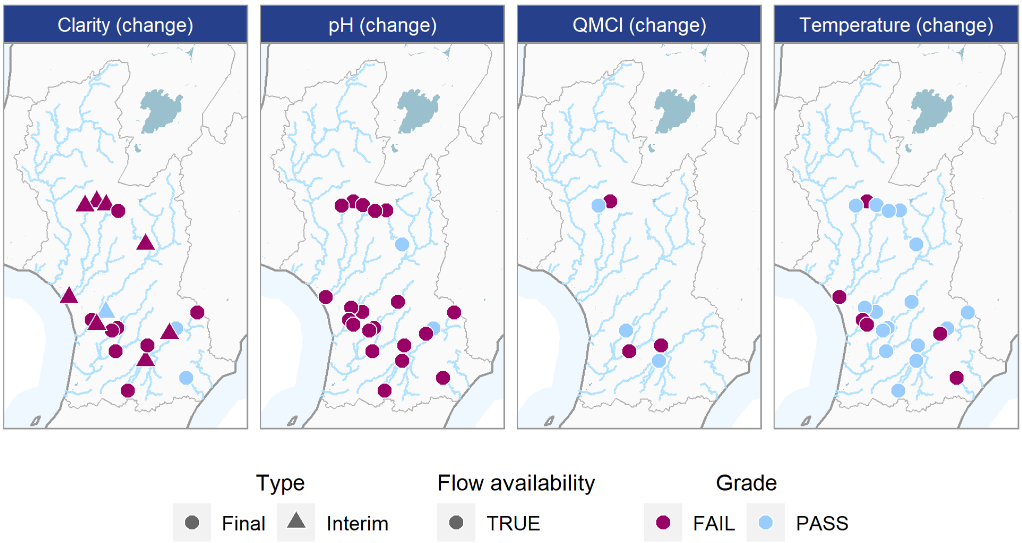

Figure 10: Maps showing discharge site state grades based on the Horizons One Plan criteria. Grades that are defined as "final" are shown with circles, and "interim" grades are shown with triangles.

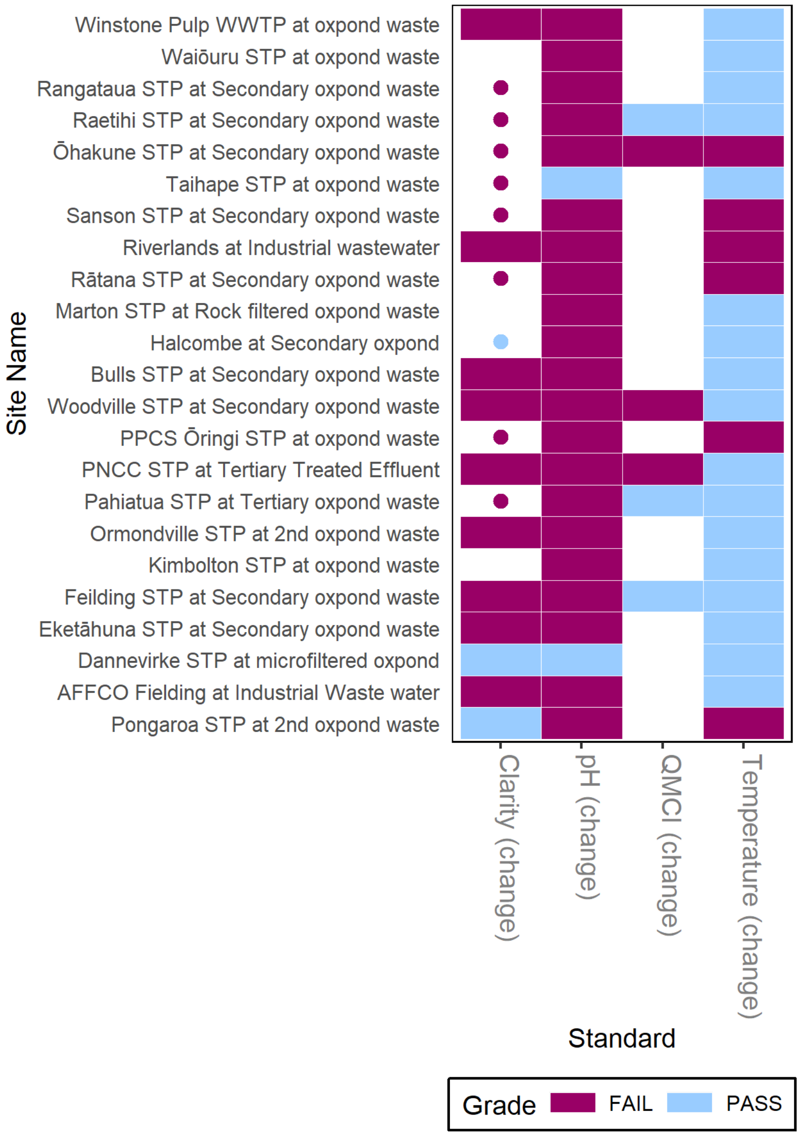

Figure 11: Assessed state for discharge river monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. No colour indicates that there were no observations, or fewer than required to define interim grades.

4.2 Lakes

The results of grading the lake sites according to the Horizons One Plan targets are shown in Figure 12. All sites failed the criteria for TN, and only Lake Koitiata passed the criteria for chlorophyll-*a* and TP. Grades varied across the region for the *E. coli* (bathing) criteria but were slightly dominated by sites passing the criteria (60%). Most grades were classed as “interim”, primarily due to the relatively recent start of monitoring at many of these lakes, and because most lakes were only monitored quarterly up until two years ago when the monitoring frequency increased to monthly.

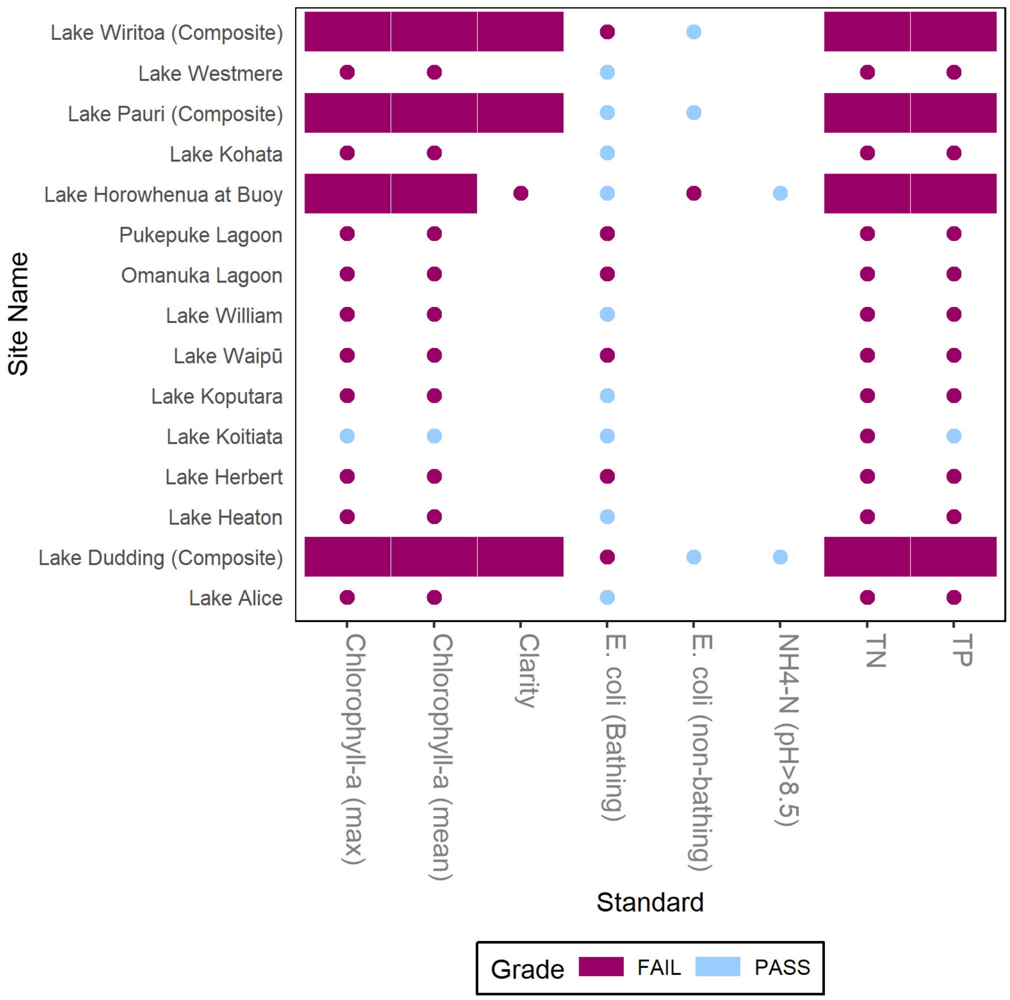

Figure 12: Assessed state for lake monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. No colour indicates that there were no observations, or fewer than required to define interim grades.

4.3 Estuary

The results of grading the estuary sites according to the Horizons One Plan targets are shown in Figure 13. All sites failed the *E. coli* targets and passed the NH4-N targets. Only one site (Mōwhānau Stream at Footbridge) had observations of clarity, and this site failed to meet the clarity target. The chlorophyll-*a* target was achieved at 4 out of 6 sites. The remaining variables (DO (Sat), DRP, SIN, Temperature) were dominated by failing sites (58-72 %).

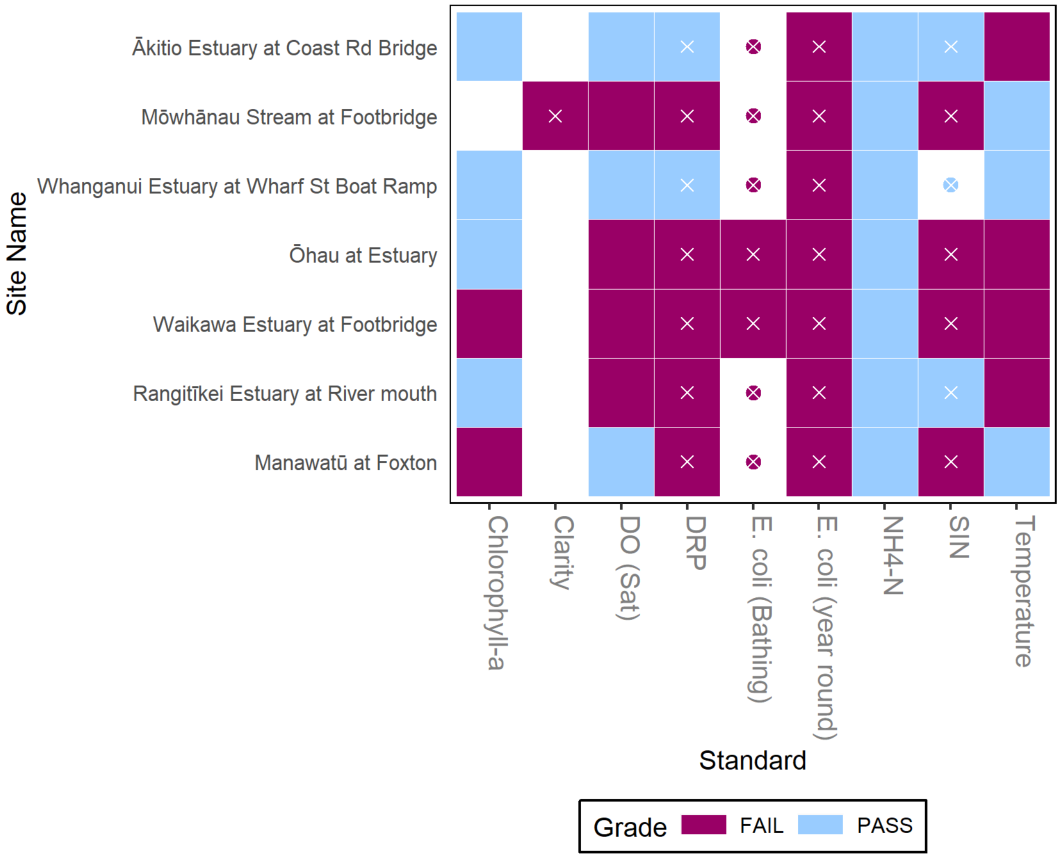

Figure 13: Assessed state for estuary monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

4.4 Coastal

The results of grading the coastal monitoring sites according to the Horizons One Plan targets are shown in Figure 14. All sites passed the NH4N target, and all sites failed the TN, TP and Enterococci (bathing) targets. The grades for the remaining targets (Chlorophyll-*a*, Enterococci (non-bathing) and Faecal Coliforms) varied across sites, with between 25-50% of sites assigned pass grades.

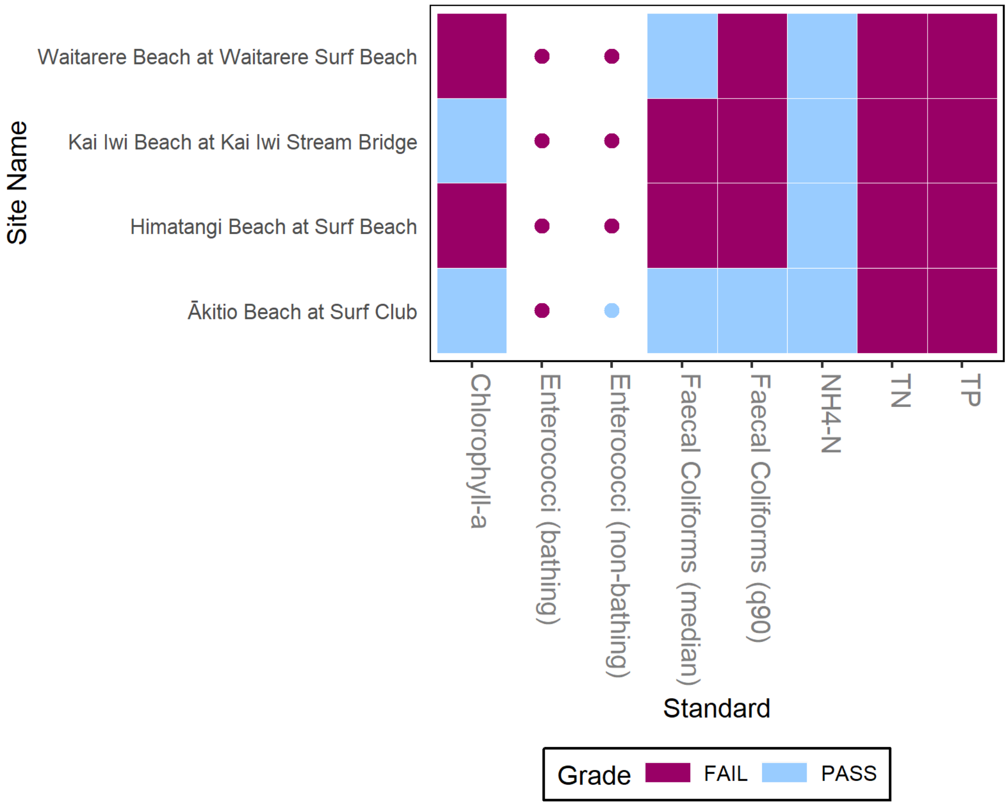

Figure 14: Assessed state for coastal monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. No colour indicates that there were no observations, or fewer than required to define interim grades.

5 Results for trends

5.1 Rivers

5.1.1 SoE Sites

Following the application of the filtering rules described in section 3.2.1, the total number of sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final SoE trend assessments is presented in Table 4.

Table 4. River water quality variables and SoE site numbers for which 10-, 20- and 30-year trends were analysed by this study.

Variable	Number of sites	Number of sites that complied with filtering rules		
		10 years	20 years	30 years
Chl_a	60	29	0	0
CLAR	110	45	10	4
DO_Sat	112	95	1	0
DRP	112	100	28	6
ECOLI	110	94	28	0
MCI	80	72	24	4
NH4N	112	97	25	6
Peri_fils	61	51	0	0
Peri_mats	61	51	0	0
pH	112	98	0	0
QMCI	80	72	0	0
sCBOD5	82	10	0	0
SIN	112	100	28	6
TEMP	112	99	27	6
Vol_Mat	88	25	1	0

5.1.1.1 10 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river SoE sites for the10 year trend period are mapped in Figure 15 and shown in summary tables in Figure 16 (Manawatū FMU) and Figure 17 (all other FMUs).

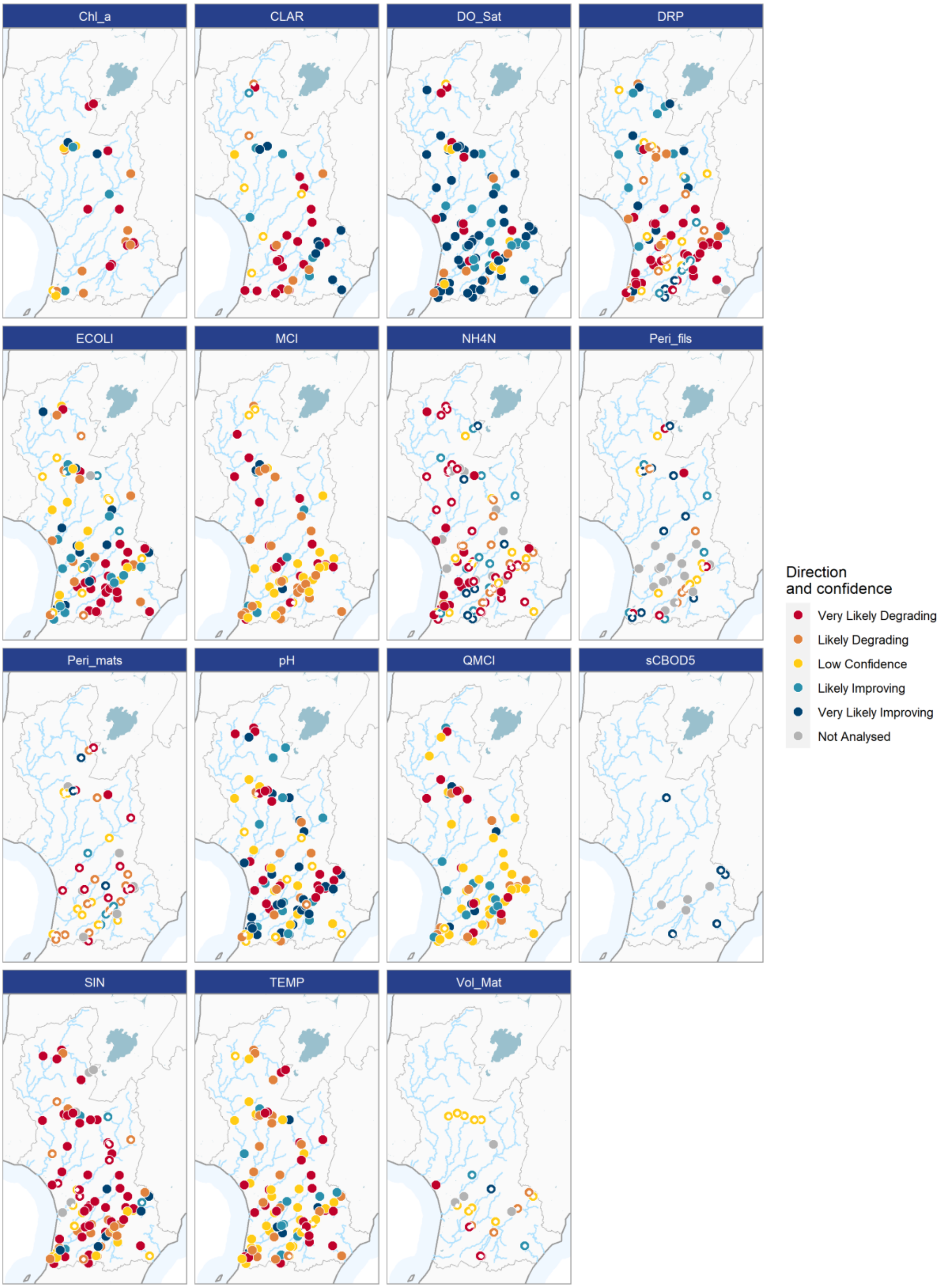

Figure 15: Map of river SoE sites classified by 10 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

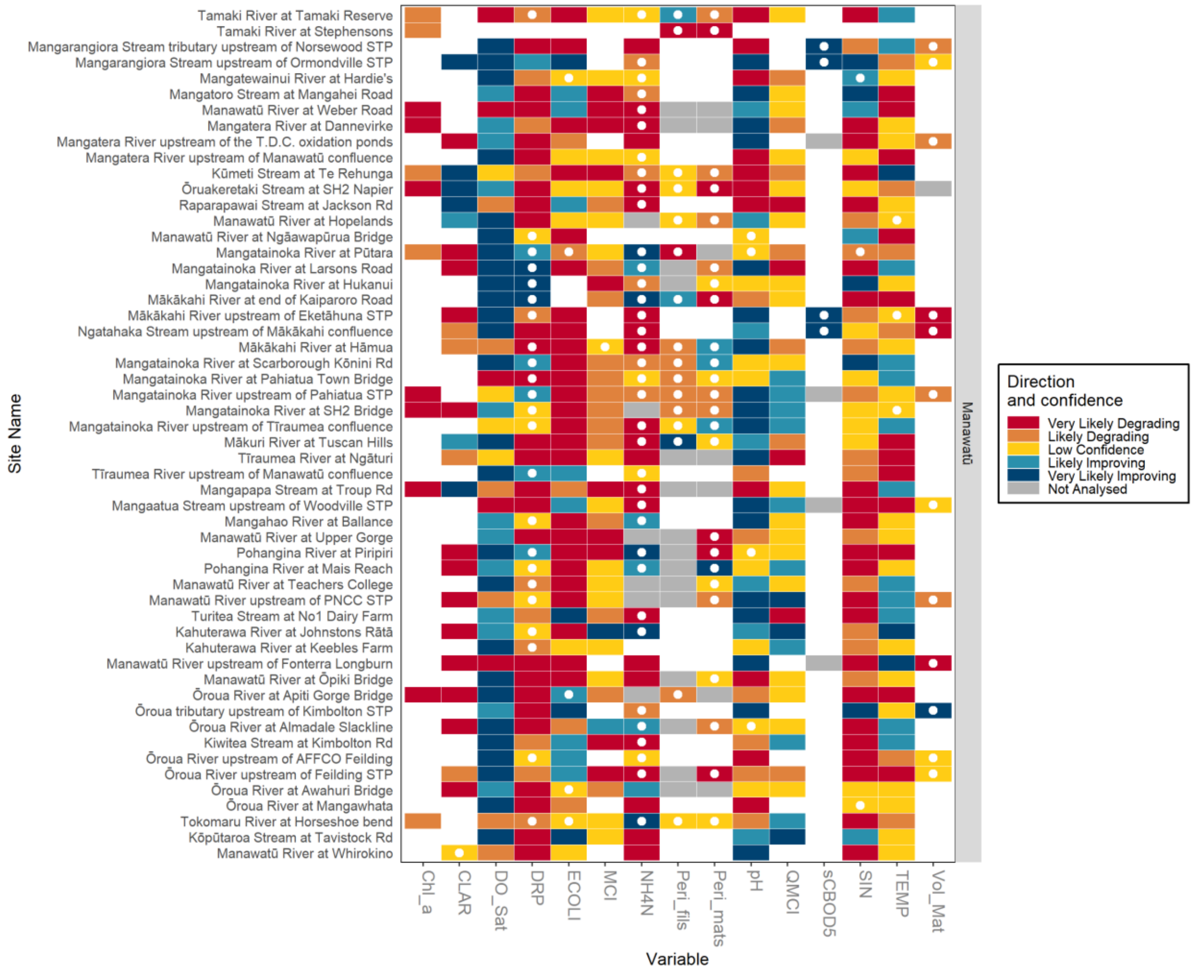

Figure 16: Assessed 10-year raw water quality trend at SoE sites in the Manawatū FMU classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

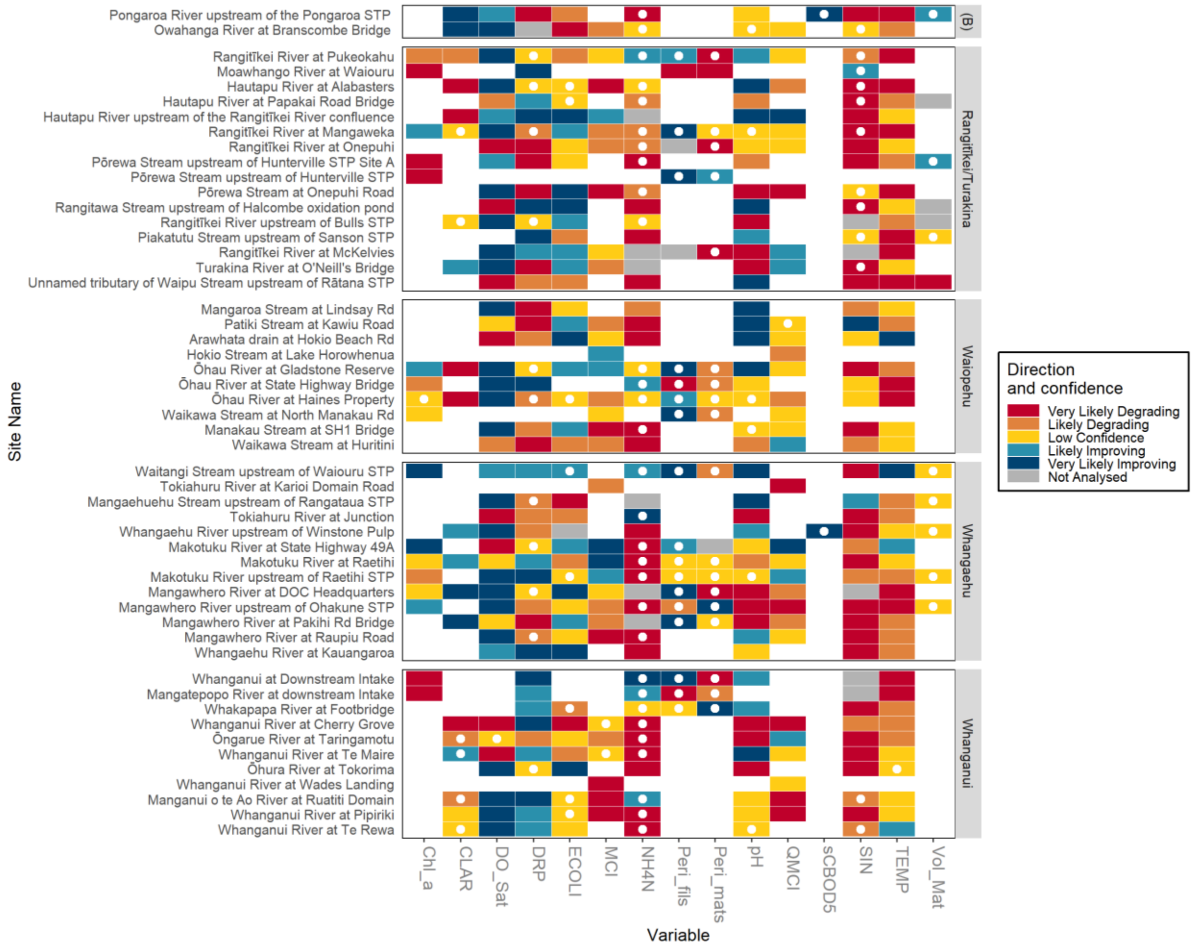

Figure 17: Assessed 10-year raw water quality trend at SoE sites outside of the Manawatū FMU classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.1.1.2 20 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river SoE sites for the 20 year trend period is mapped in Figure 18 and shown in a summary table Figure 19.

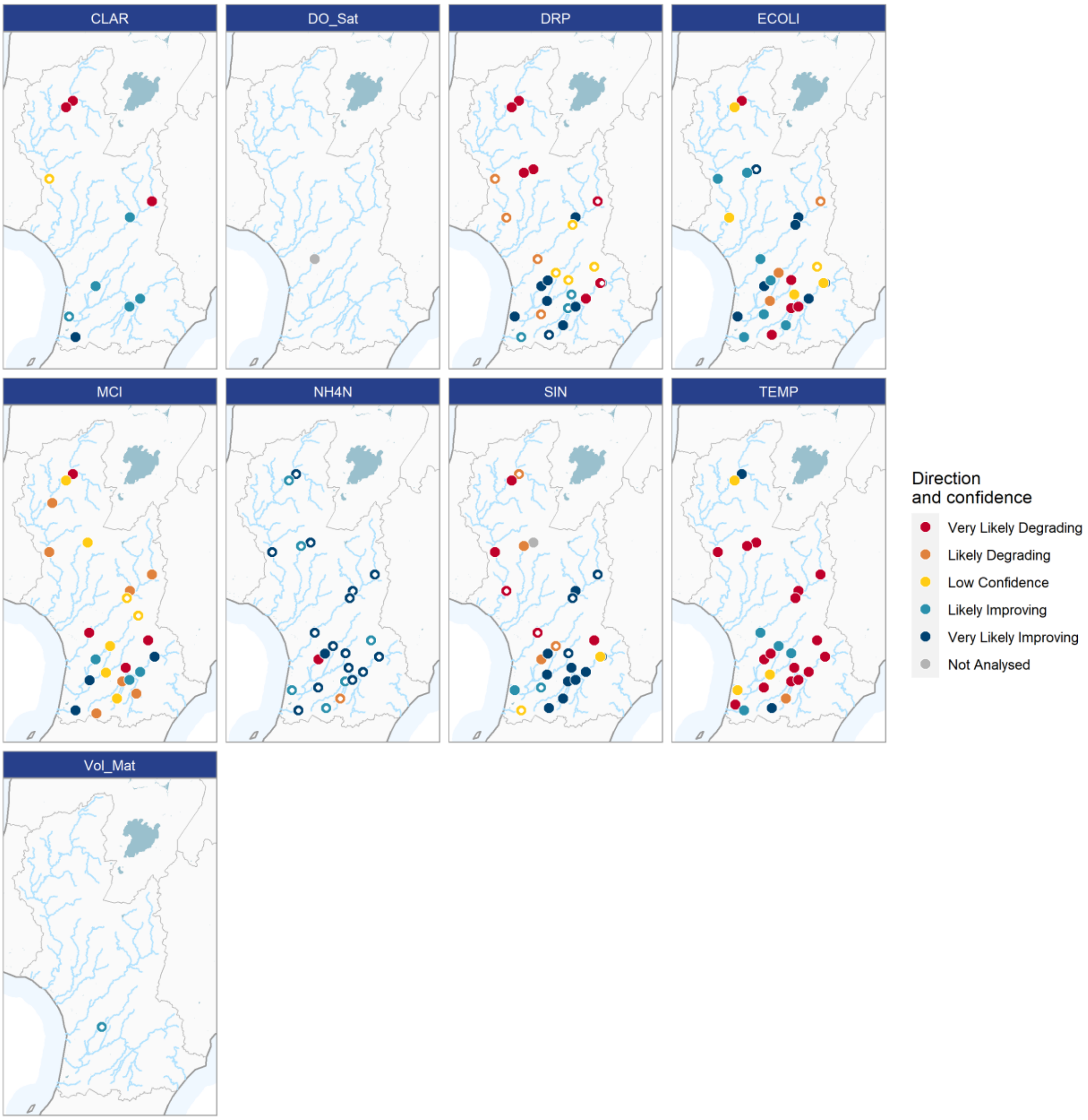

Figure 18: Map of river SoE sites classified by 20 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

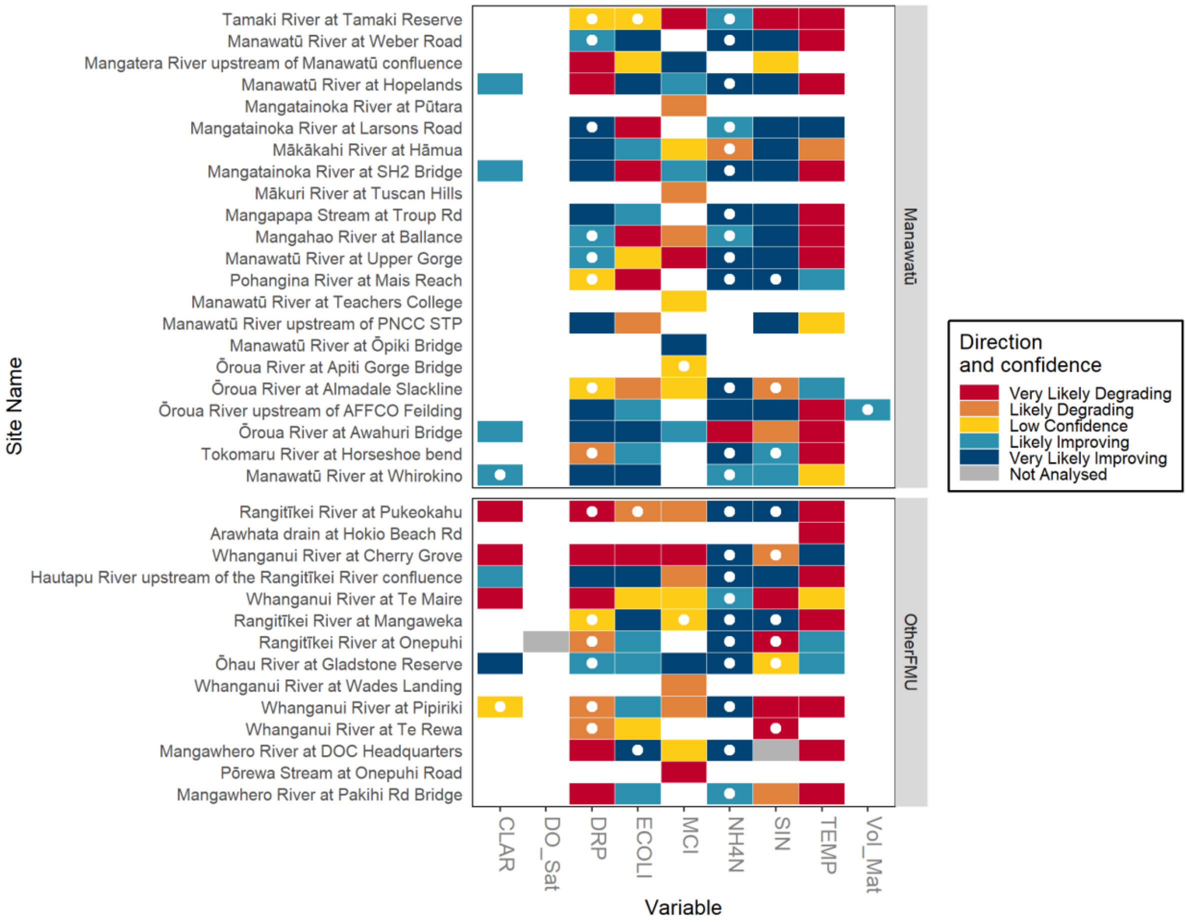

Figure 19: Assessed 20-year raw water quality trend at SoE sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.1.1.3 30 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river SoE sites for the 30 year trend period is mapped in Figure 20 and shown in a summary table in Figure 21.

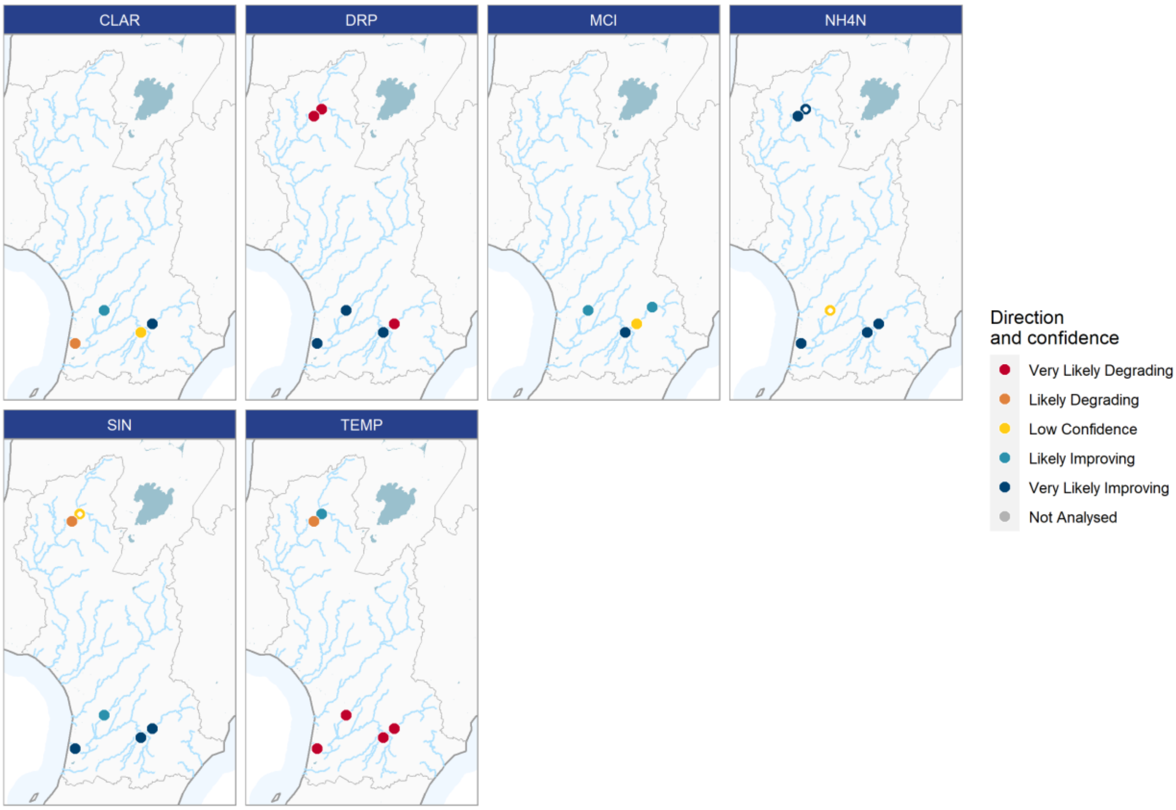

Figure 20: Map of river SoE sites classified by 30 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

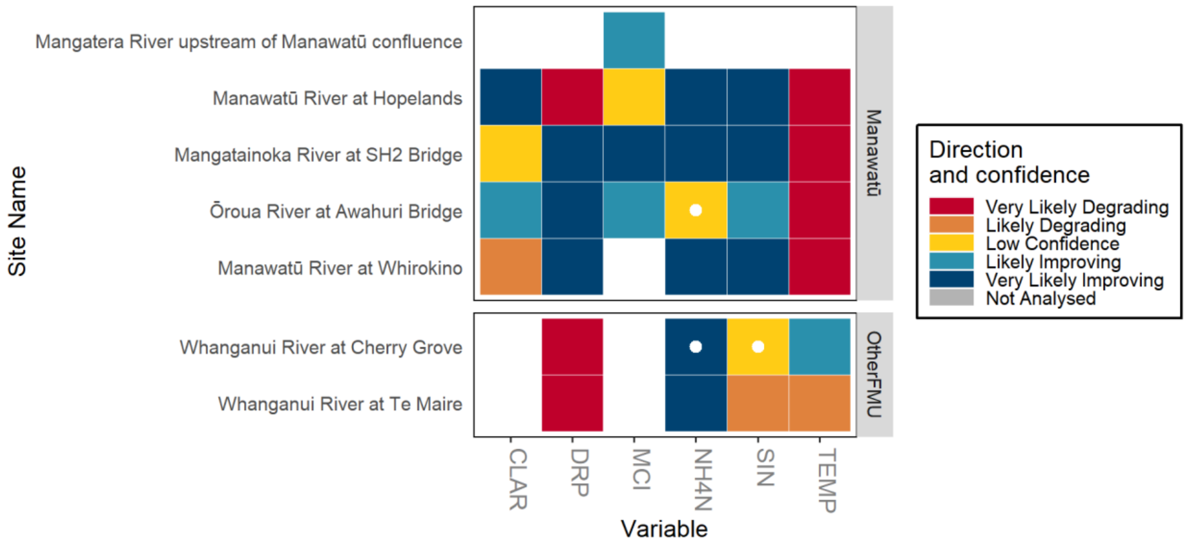

Figure 21: Assessed 30-year raw water quality trend at SoE sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.1.1.4 Aggregate trends

Figure 22 and Figure 23 show colour coded bar charts representing the proportions of SoE sites with improving and degrading water quality trends based on the categories defined in Table 3 for the 10- and 20-year trend periods, respectively. Blue colours indicate sites with improving trends, and red-orange colours indicate sites with degrading trends. Interpretation of these plots should also take into account that there were variable numbers of sites included in the different time periods (see Table 4).

For the 10 year trends, seven of the 15 water quality variables had more than half of sites classed as “likely degrading” or “Very likely degrading” (Chl_a, CLAR, DRP, MCI, NH4N, Peri_mats, SIN), whereas only two variables had more than half of sites classes as “likley improving” or “very likley improving” (DO_Sat, sCBOD5).

For the 20 year trends, only one of the seven water quality variables had more than half of sites classed as “likely degrading” or “Very likely degrading” (TEMP), whereas four variables had more than half of sites classes as “likely improving” or “very likely improving” (CLAR, ECOLI, NH4N, SIN). While the 20-year aggregate trends appear to paint a better picture of the aggregate trends in the region, it is noted that there are fewer sites included in the 20 year trend assessment (Table 4).

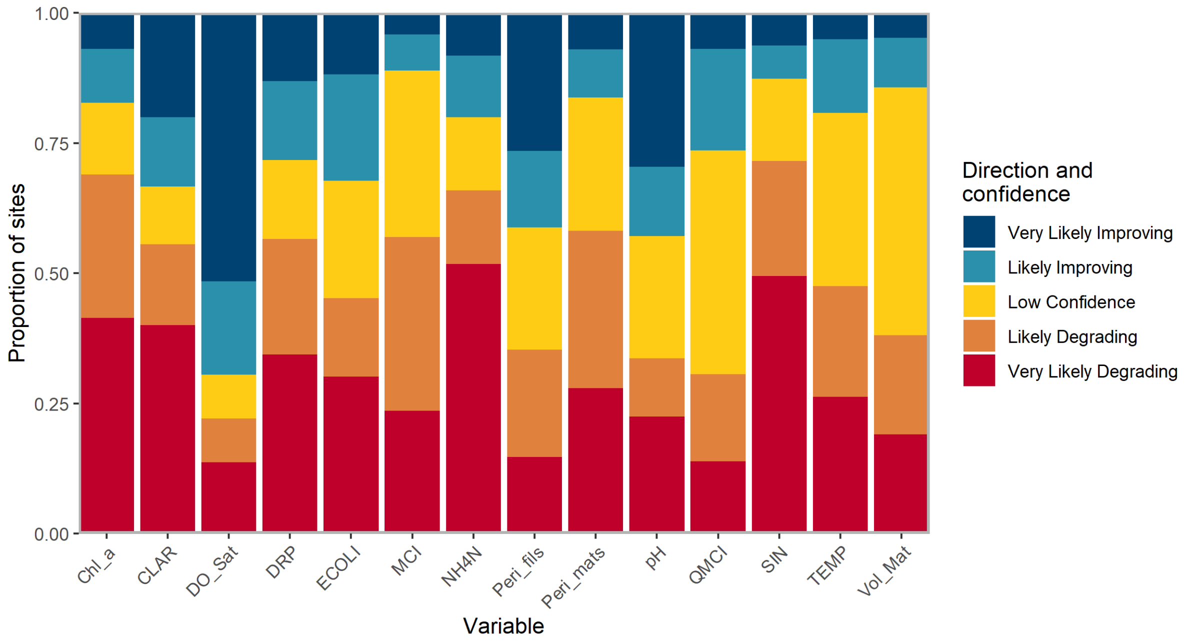

Figure 22. Summary plot representing the proportion of SoE river sites each categorical level of confidence and direction for 10-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

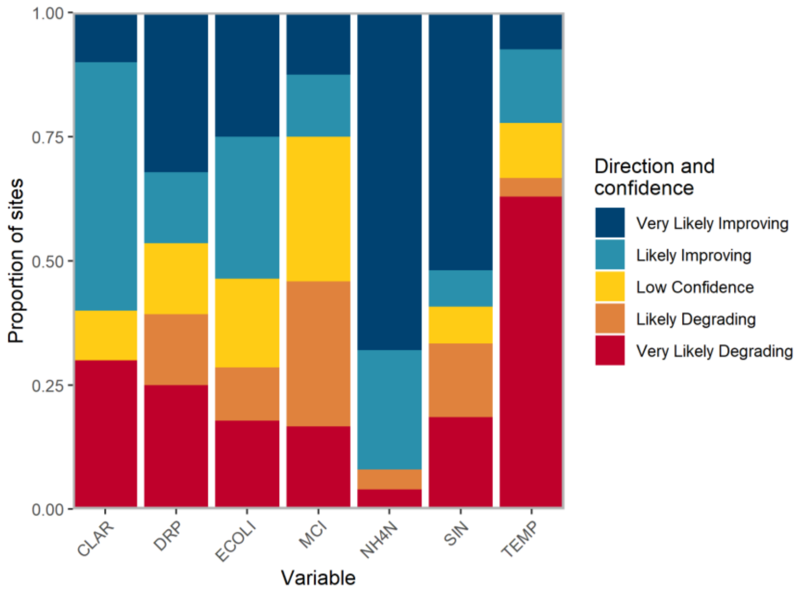

Figure 23. Summary plot representing the proportion of SoE river sites each categorical level of confidence and direction for 20-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

5.1.2 Impact sites

Following the application of the filtering rules described in section 3.2.1, the total number of impact sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final impact site trend assessments is presented in Table 5. There were no impact sites that met the minimum data requirements for 20 of 30 year trends.

Table 5. River water quality variables and impact site numbers for which 10-year trends were analysed by this study.

Variable	Number of sites	Number of sites that complied with filtering rules for 10 year trends
Chl_a	9	5
CLAR	27	9
DO_Sat	27	27
DRP	27	27
ECOLI	27	27
MCI	7	7
NH4N	27	27
Peri_fils	10	8
Peri_mats	10	8
pH	27	27
QMCI	7	7

sCBOD5	28	10
SIN	27	27
TEMP	27	27
Vol_Mat	28	26

5.1.2.1 10 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river impact sites for the 10 year trend period are mapped in Figure 24 and shown in a summary table in Figure 25.

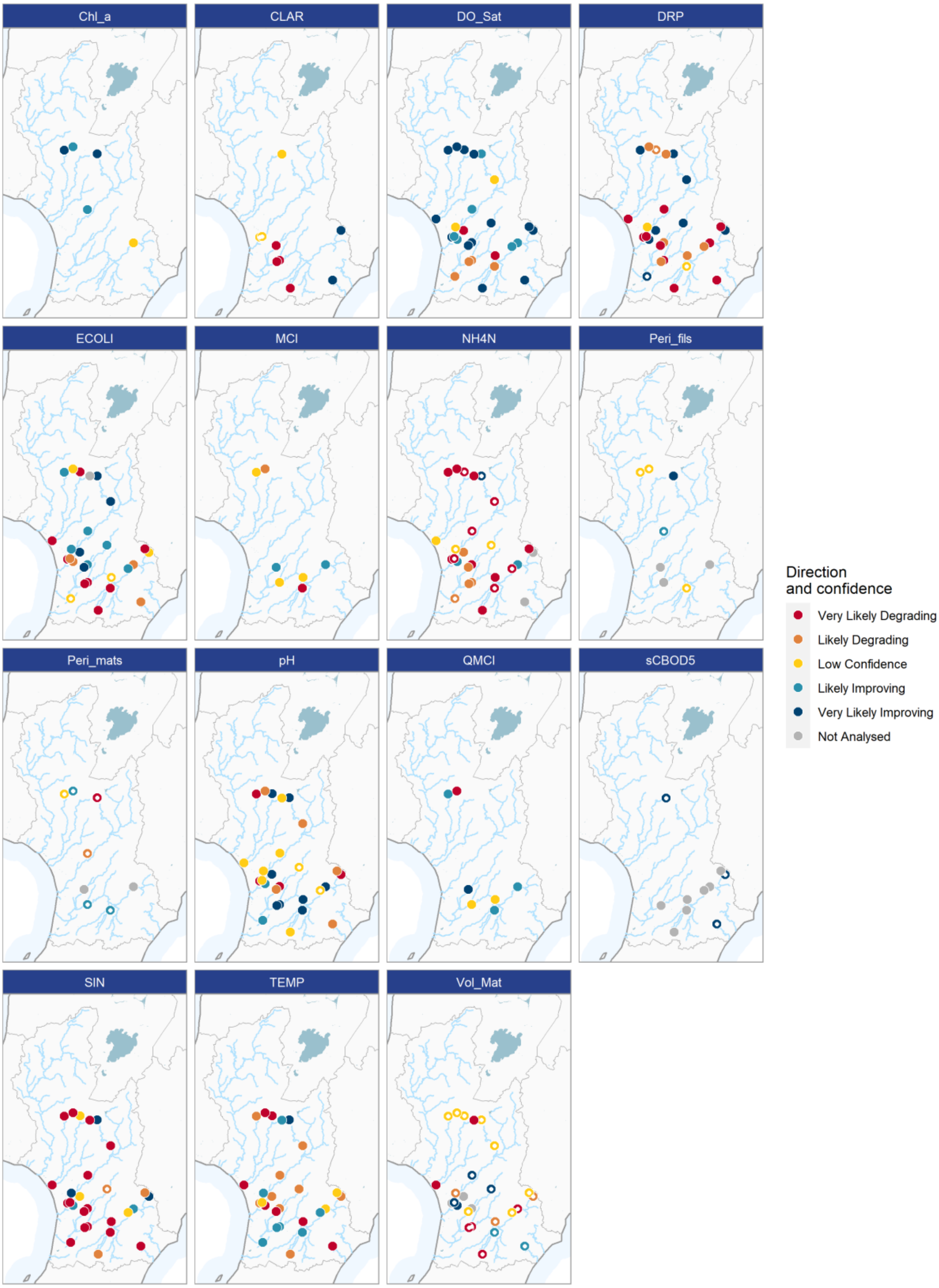

Figure 24: Map of river impact sites classified by 10 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

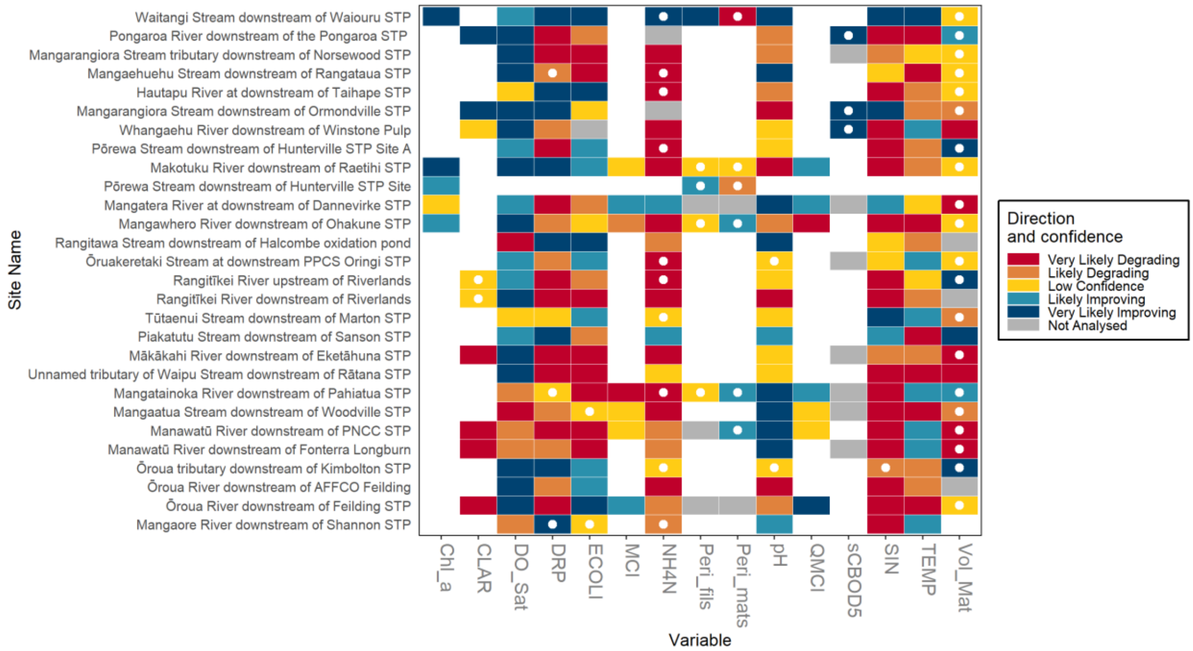

Figure 25: Assessed 10-year raw water quality trend at impact sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.1.2.2 Aggregate trends

Figure 26 shows colour coded bar charts representing the proportions of impact sites with improving and degrading water quality trends based on the categories defined in Table 3 for the 10-year trend period. Four of the eight water quality variables had more than half of sites classed as "likely degrading" or "Very likely degrading" (DRP, NH4N, SIN, TEMP), whereas only one variable had more than half of sites classes as "likely improving" or "very likely improving" (DO_Sat).

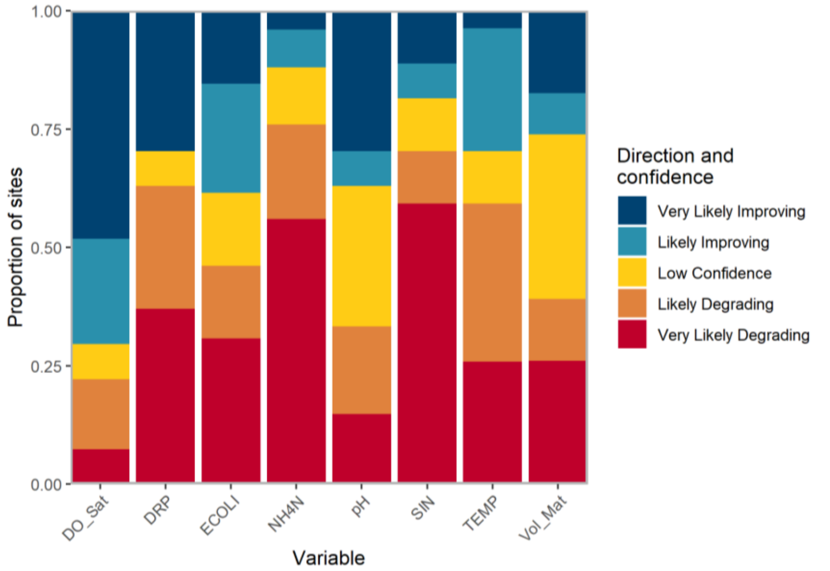

Figure 26. Summary plot representing the proportion of impact sites each categorical level of confidence and direction for 10-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

5.1.3 Discharge sites

Following the application of the filtering rules described in section 3.2.1, the total number of discharge sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final discharge site trend assessments is presented in Table 6. There were no discharge sites that met the minimum data requirements for 30 year trends.

Table 6. River water quality variables and discharge site numbers for which 10- and 20-year trends were analysed by this study.

Variable	Number of sites	Number of sites that complied with filtering rules	
		10 years	20 years
DRP	34	23	2
ECOLI	34	24	2
NH4N	34	21	1
sCBOD5	34	23	0
SIN	34	23	2
Vol_Mat	34	24	2

5.1.3.1 10 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river discharge sites for the 10 year trend period are mapped in Figure 27 and shown in a summary table in Figure 28.

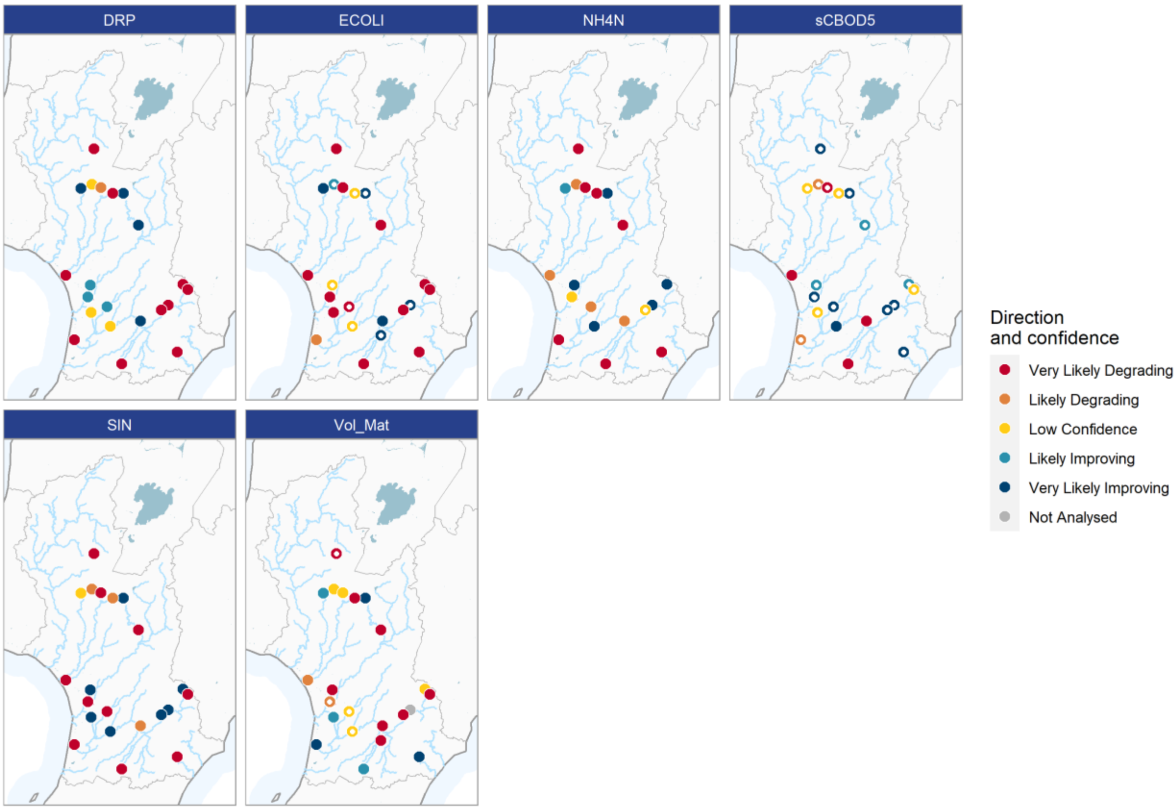

Figure 27: Map of river discharge sites classified by 10 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

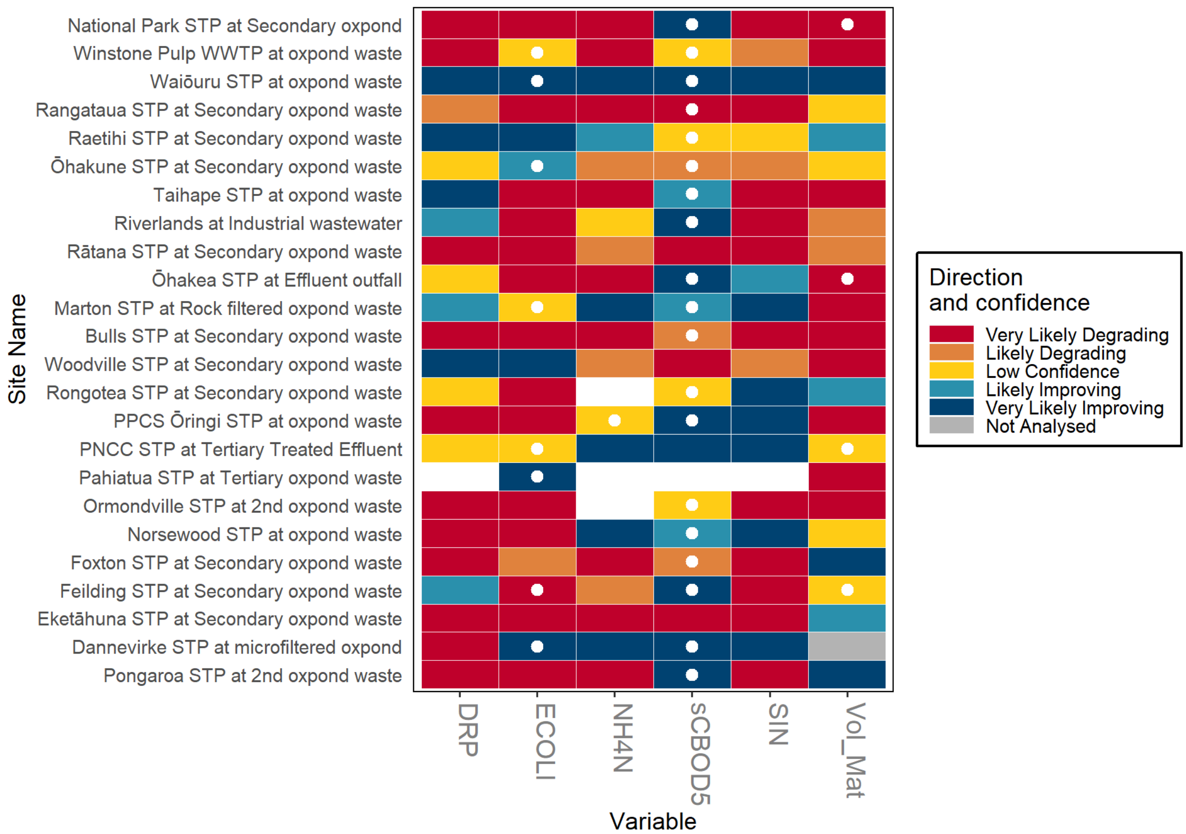

Figure 28: Assessed 10-year raw water quality trend at discharge sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.1.3.2 20 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river discharge sites for the 20 year trend period are mapped in Figure 29 and shown in a summary table in Figure 30.

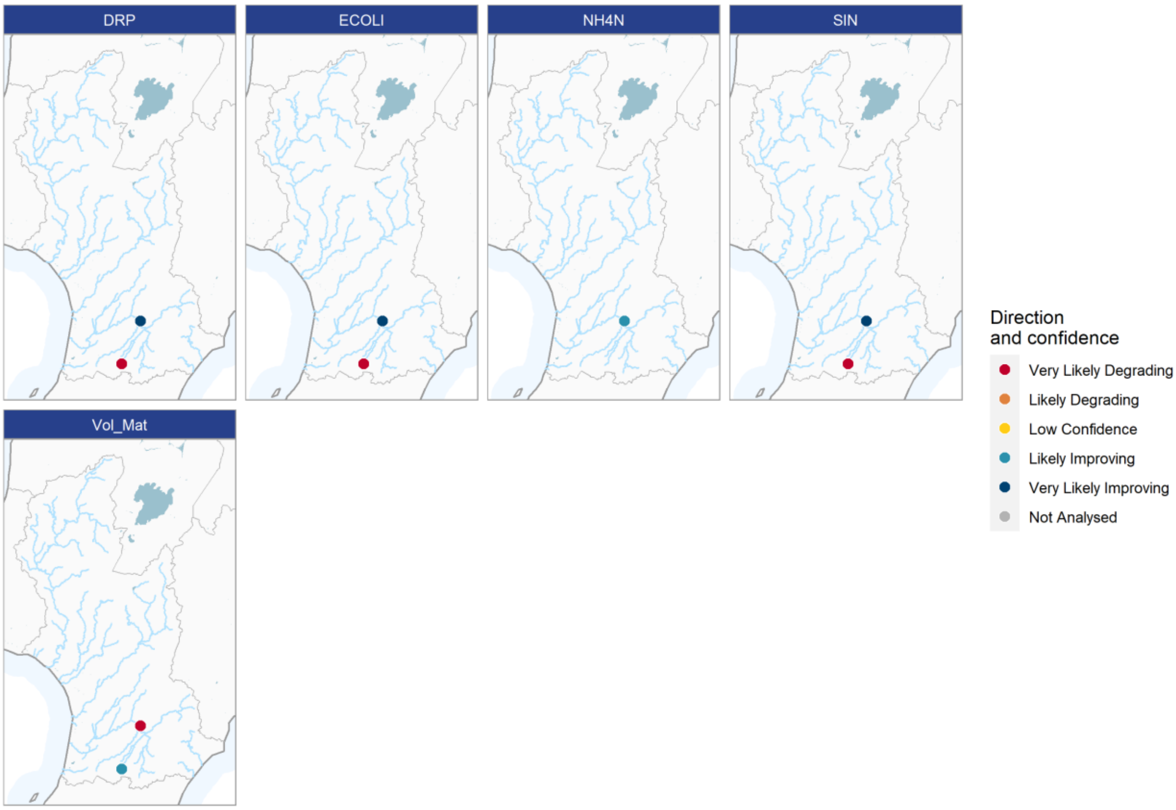

Figure 29: Map of river discharge sites classified by 20 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

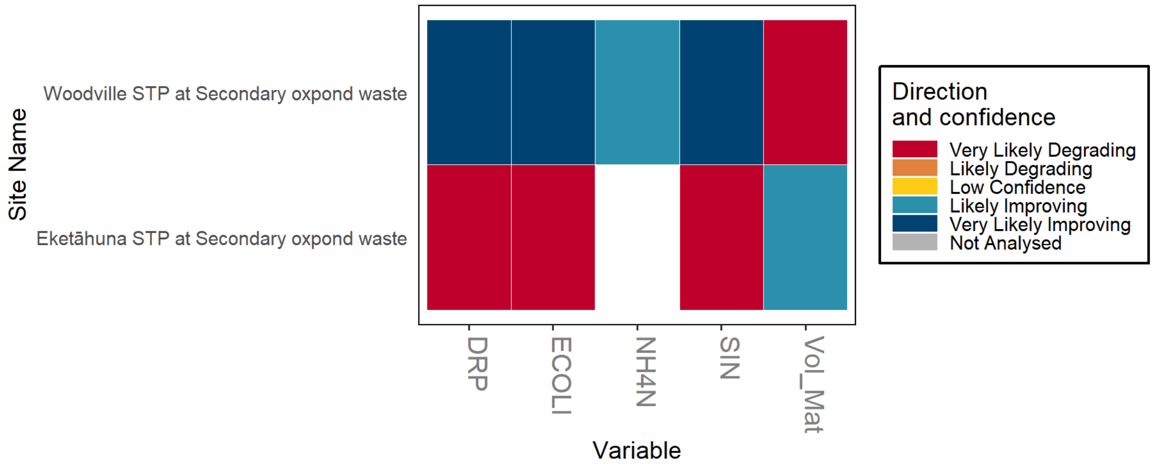

Figure 30: Assessed 20-year raw water quality trend at discharge sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.1.3.3 Aggregate trends

Figure 31 shows colour coded bar charts representing the proportions of discharge sites with improving and degrading water quality trends based on the categories defined in Table 3 for the 10-year trend period. All but one of the variables (sCBOD5) had more than half of sites classed as “likley degrading” or “Very likely degrading” (DRP, ECOLI, NH4N, SIN, Vol_Mat).

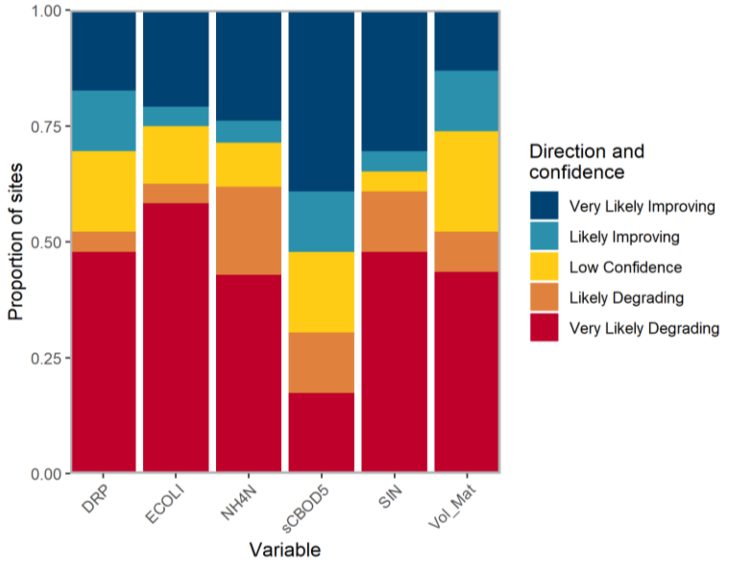

Figure 31. Summary plot representing the proportion of discharge sites each categorical level of confidence and direction for 10-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

5.2 Lakes

Following the application of the filtering rules described in section 3.2.1, the total number of lake sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final lake site trend assessments is presented in Figure 9. There were no lake sites that met the minimum data requirements for 20 or 30 year trends.

Table 7. Lake water quality variables and lake site numbers for which 10-year trends were analysed by this study.

Variable	Number of sites	Number of sites that complied with filtering rules for 10 year trends
Chl_a	15	4
ECOLI	15	3
NH4N	15	4
TN	15	4
TP	15	4

The LAWA categorical description for the raw (with high censor filter) trends for the lake sites for the 10 year trend period are shown in a summary table in Figure 32. Across the four sites there was a dominance of degrading trends for Chl_a, and a dominance for improving trends for the remaining variables (ECOLI, NH4N, TN, TP).

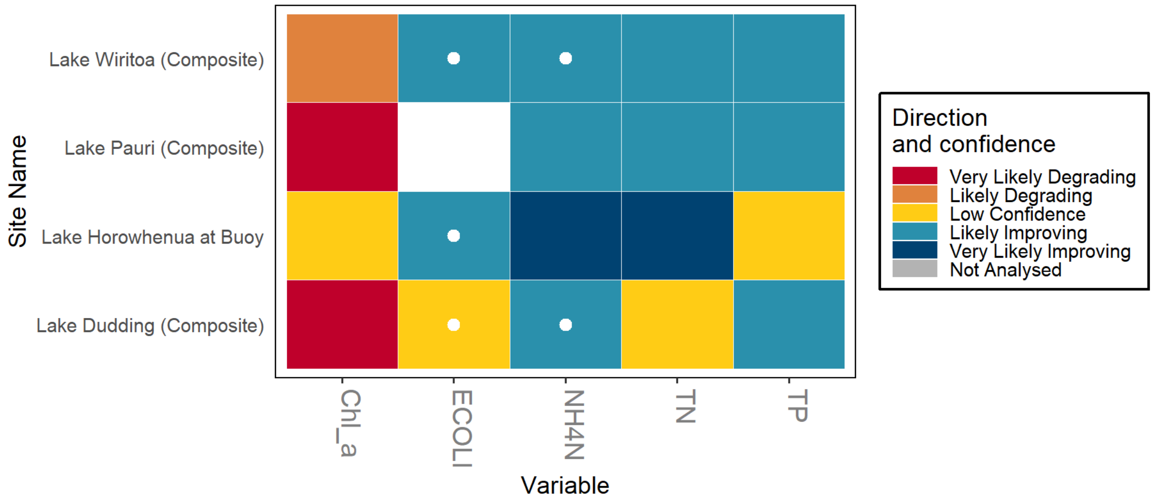

Figure 32: Assessed 10-year raw water quality trend at lake sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.3 Estuary

Following the application of the filtering rules described in section 3.2.1, the total number of estuary sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final estuary site trend assessments is presented in Table 8. There were no estuary sites that met the minimum data requirements for 20 or 30 year trends.

Table 8. Estuary water quality variables and estuary site numbers for which 10-year trends were analysed by this study.

Variable	Number of sites	Number of sites that complied with filtering rules for 10 year trends
Chl_a	6	4
DO_Sat	7	6
DRP	7	6
ECOLI	7	6
NH4N	7	6
pH	1	1
SIN	7	3
TEMP	7	6

The LAWA categorical description for the raw (with high censor filter) trends for the estuary sites for the 10 year trend period are shown in a summary table in Figure 33. All six sites had very likely degrading trends for NH4N. and a dominance for improving trends for Chl_a and DO_Sat. Mōwhānau Stream at Footbridge showed very likely degrading trends for four of the six variables evaluated at the site.

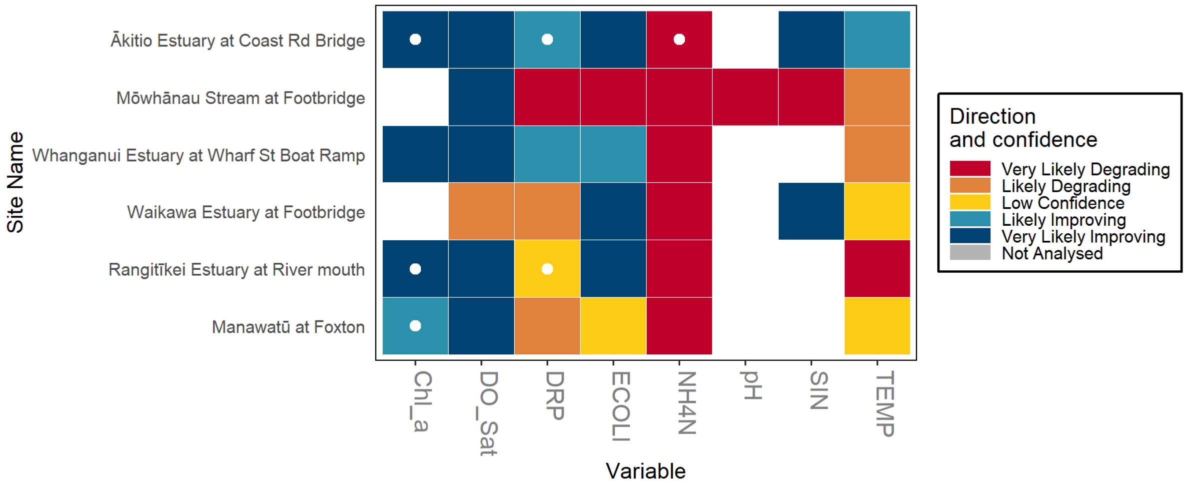

Figure 33: Assessed 10-year raw water quality trend at estuary sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

5.4 Coastal

Following the application of the filtering rules described in section 3.2.1, the total number of coastal sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final coastal site trend assessments is presented in Table 9. There were no coastal sites that met the minimum data requirements for 20 or 30 year trends.

Table 9. Coastal water quality variables and coastal site numbers for which 10-year trends were analysed by this study.

Variable	Number of sites	Number of sites that complied with filtering rules for 10 year trends
Chl_a	4	4
NH4N	4	3
TN	4	4
TP	4	4

The LAWA categorical description for the raw (with high censor filter) trends for the coastal sites for the 10 year trend period are shown in a summary table in Figure 32. Across the four sites there was a dominance of degrading trends for TN, and a dominance for improving trends for Chl_a and NH4N.

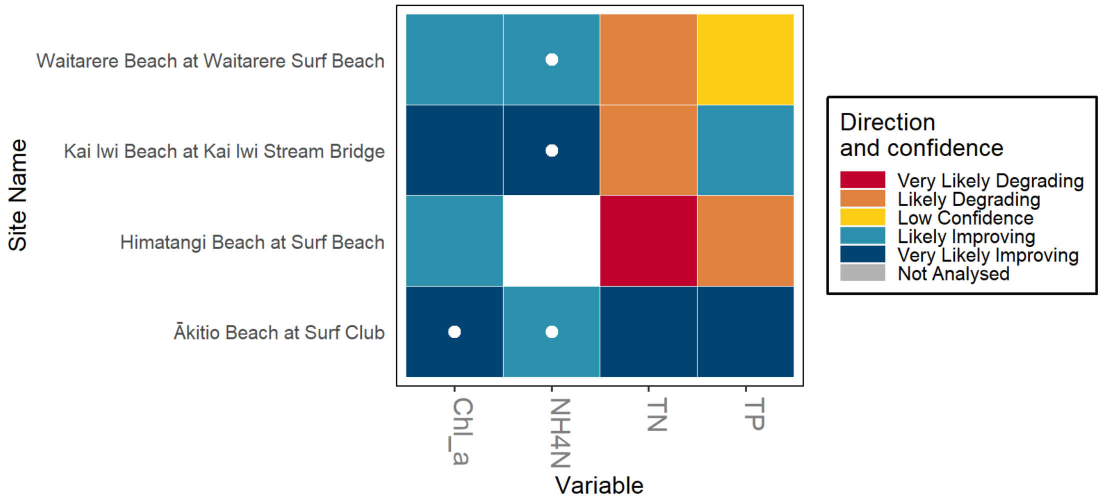

Figure 34: Assessed 10-year raw water quality trend at coastal sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

6 Comparison of state and trends

The relevance of trends and identification of appropriate management actions is dependent on many factors, including the current state and the direction and magnitude of the trends. Figure 35 to Figure 39 show the distribution of 10-year Sen slopes for each variable separated by One Plan grades (evaluated for the most recent 5 years) for SoE, impact, lake, estuary and coastal sites. Note, in some cases the state target did not have a corresponding trend calculated (i.e., maximum ammoniacal-N, *E. coli* bathing); in these cases, the Sen slopes shown in the figures represent the trends evaluated for all data for the corresponding variable. The same data are presented in Appendix D but shown as scatter plots with the continuous compliance statistic (e.g., median NH4-N) on the x-axis and annual Sen slope with on the y-axis, including the 90% confidence intervals for the Sen slopes.

6.1 Rivers

Sites of all grades were associated with both improving and degrading trends for both SoE and impact sites. The largest degrading trends were associated with sites with poor state grades, almost uniformly across all variables. For the *E. coli* grades, the largest improving trends were also associated with sites with the lowest state grades. For the NH4N grades, the largest degrading trends were associated with sites that had passing grades. The site with the worst state for Periphyton Mats (Moawhango at Waiouru), also had the largest degrading trends (by over and order of magnitude), with a Sen slope of 3% cover per year.

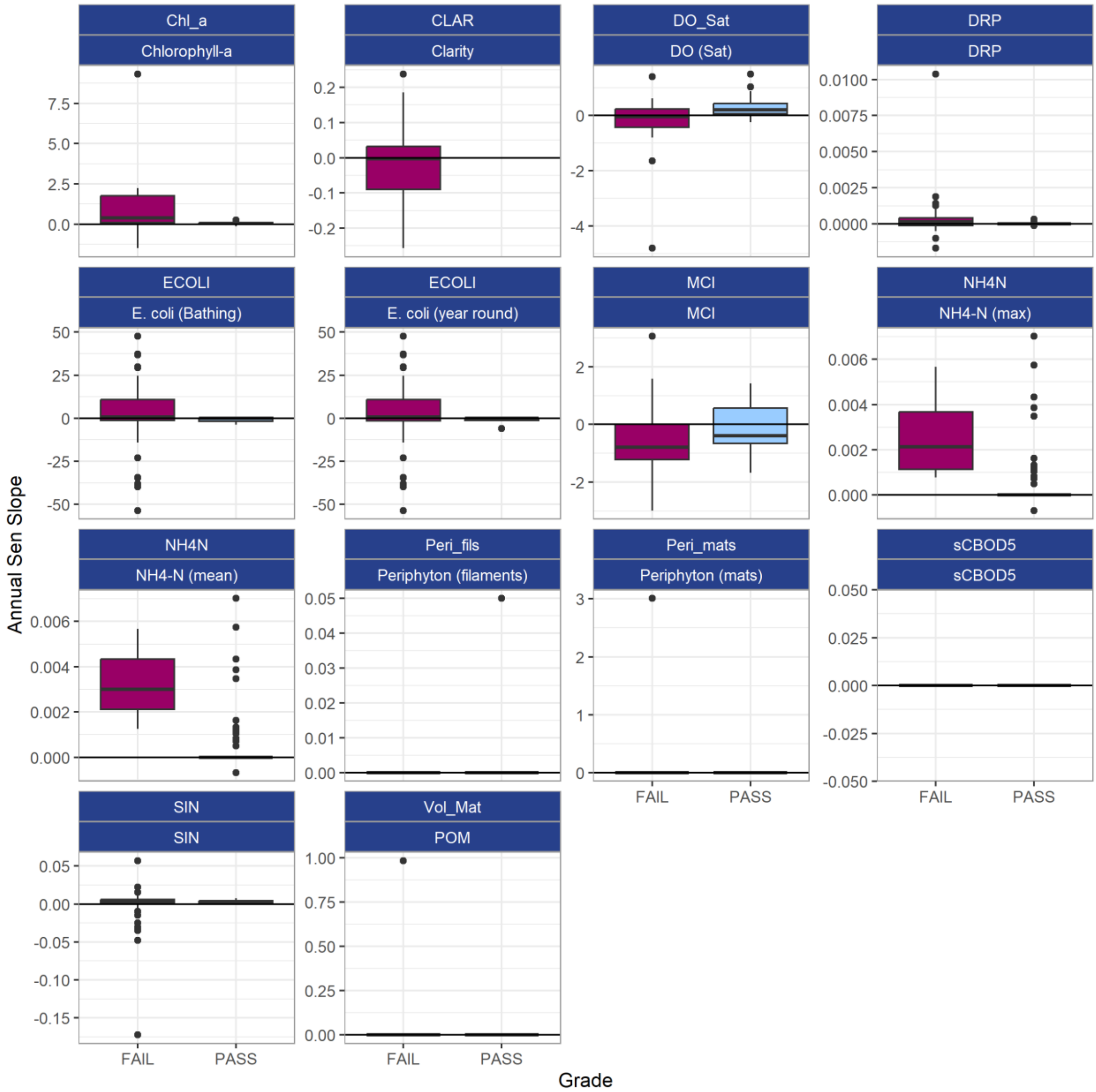

Figure 35: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for river SoE sites categorised by their (5-year) One Plan grades. Note, for CLAR, DO_Sat and MCI negative Sen Slopes indicate degradation; for other variables negative Sen slopes indicate improvement. The first row of plot labels is the trend variable, and the second row is the One Plan target name.

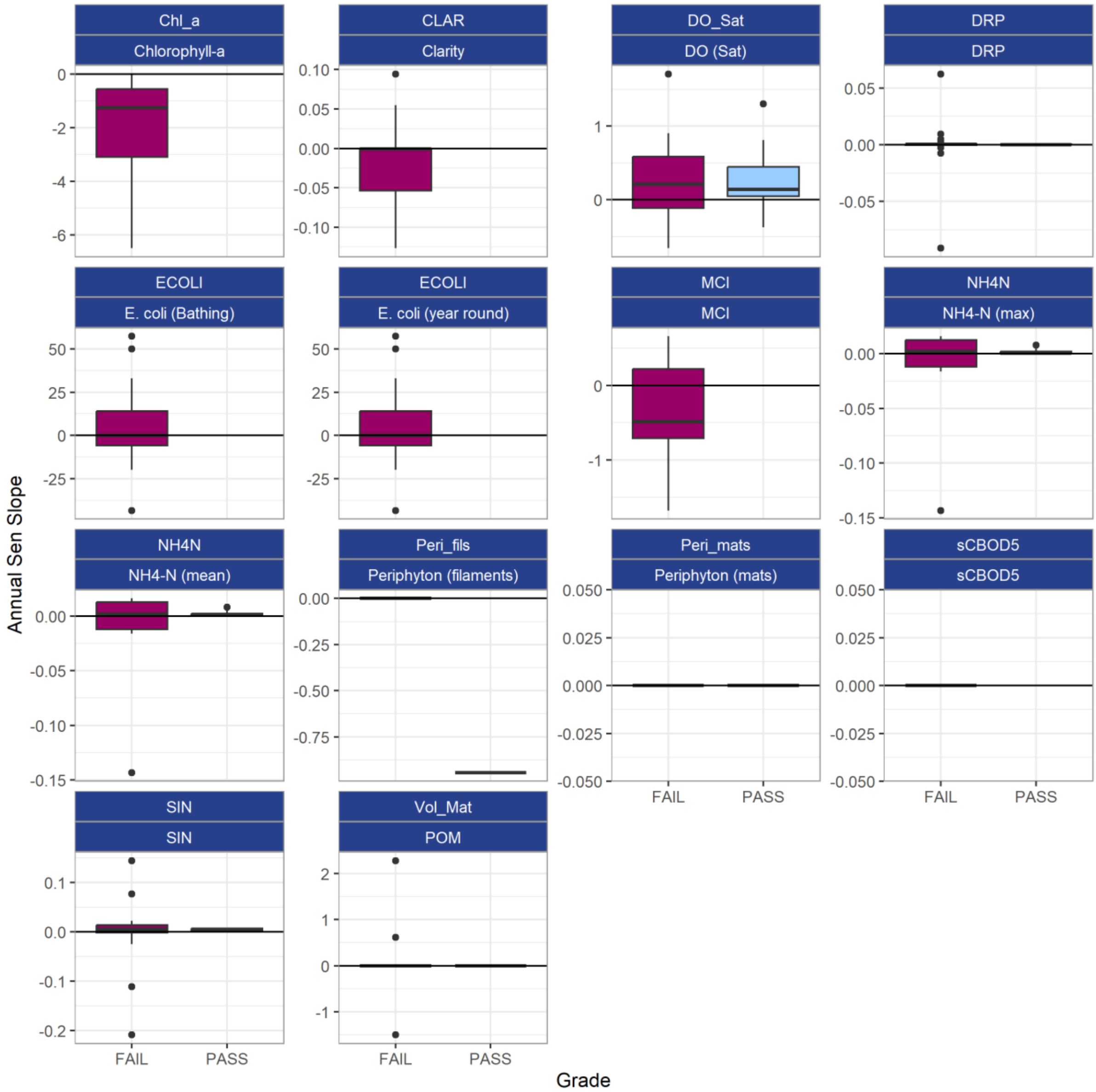

Figure 36: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for river impact sites categorised by their (5-year) One Plan grades. Note, for CLAR, DO_Sat and MCI negative Sen Slopes indicate degradation; for other variables negative Sen slopes indicate improvement. The first row of plot labels is the trend variable and the second row is the One Plan target name.

6.2 Lakes

The largest degrading trends in Lakes were associated with poor state grades, almost uniformly across all variables. For the *E. coli* trends, all sites had Sen slopes of zero, i.e., trend slopes could not be quantified given the detection limit and precision of the monitoring. All sites are failing to meet the chlorophyll-*a* One Plan targets, and with the exception of Lake Horowhenua at Buoy, the site trends indicate further degradation. In contrast, for TP and TN, although sites are uniformly failing the One Plan targets, three out for four sites had improving trends.

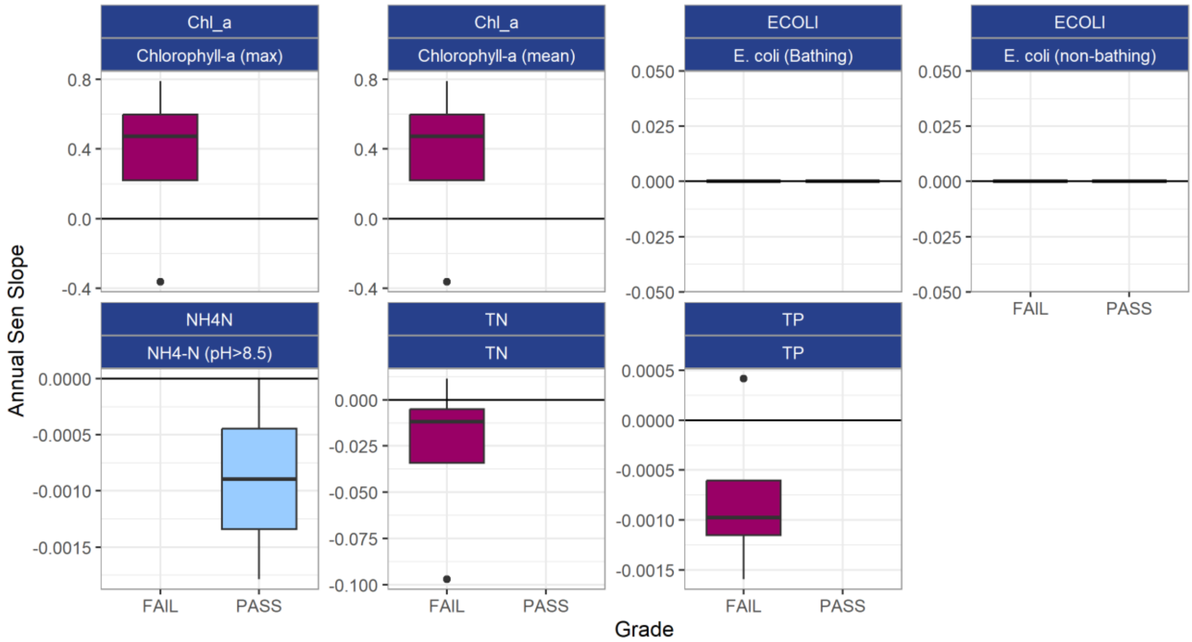

Figure 37: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for lake sites categorised by their (5-year) One Plan grades. The first row of plot labels is the trend variable and the second row is the One Plan target name.

6.3 Estuary

For DRP, TEMP and NH4N there was a pattern of increasing degrading trends with larger compliance statistic values (i.e., poorer water quality state, Appendix D, Figure 110). Improvements in DO_Sat were greatest for sites that had failed the One Plan target. Although all sites failed the One Plan *E. coli* targets, all but one site (Mōwhānau stream at Footbridge) had an improving trend in *E. coli*.

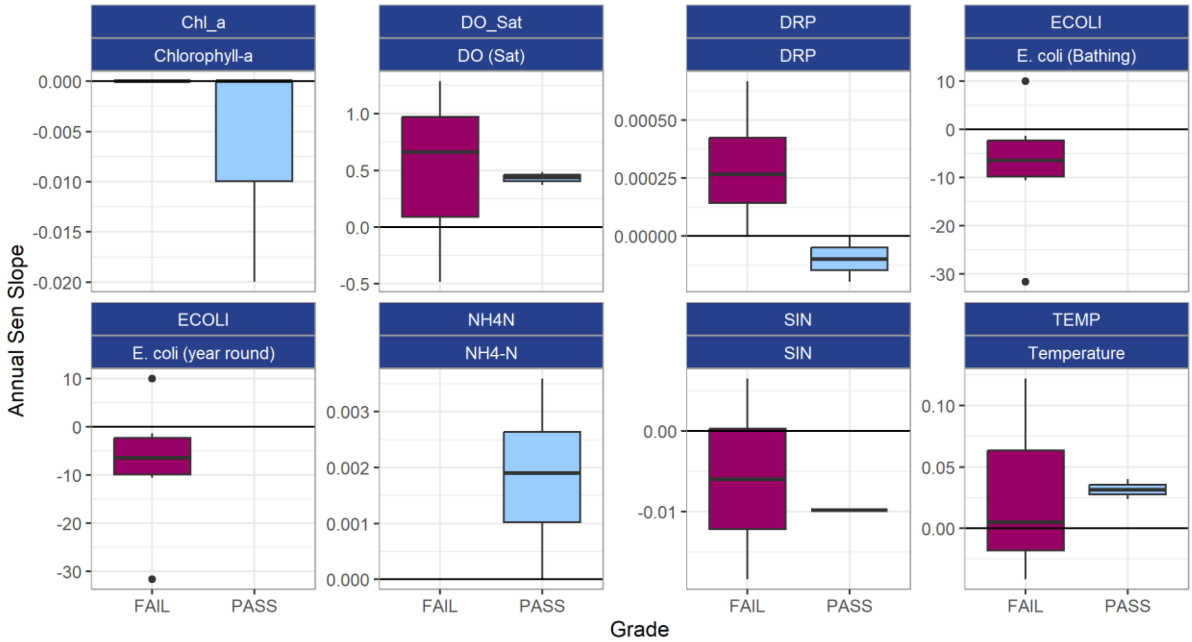

Figure 38: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for estuary sites categorised by their (5-year) One Plan grades. Note, for DO_Sat negative Sen Slopes indicate degradation; for other variables negative Sen slopes indicate improvement. The first row of plot labels is the trend variable and the second row is the One Plan target name.

6.4 Coastal

Trends in Chl_a at coastal sites indicate improvement, both for sites that have passed and failed the One Plan Chlorophyll-a target. For TN and TP there is a pattern of increasing magnitude of degrading trends with poorer water quality state (Figure 39 and Appendix D: Figure 112).

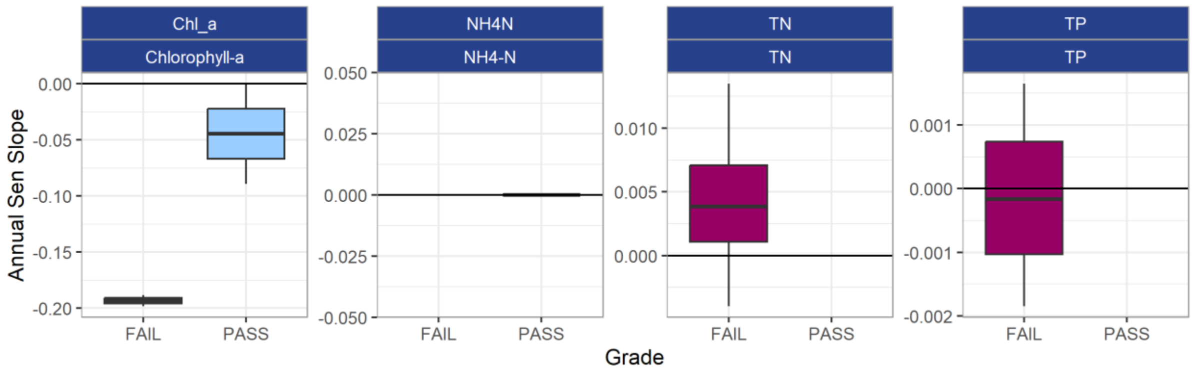

Figure 39: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for coastal sites categorised by their (5-year) One Plan grades. The first row of plot labels is the trend variable and the second row is the One Plan target name.

7 Summary

7.1 Water quality state

The most obvious pattern associated with the assessment of water quality state was that for many variables the individual sites almost uniformly passed or failed One Plan criteria. A majority of river sites failed the Horizons One Plan criteria for dissolved reactive phosphorus (DRP), macroinvertebrate community index (MCI), *E. coli* and clarity. Conversely, almost all sites passed the One Plan criteria for ammoniacal-N (NH4-N), periphyton (mats) and dissolved oxygen (sat). There were similar numbers of State of Environment sites passing and failing the One Plan criteria for chlorophyll-*a*, particulate organic matter (POM), periphyton (filaments) and soluble inorganic nitrogen (SIN) Generally, these patterns in grades were similar for the impact sites. A majority of discharge sites failed the One Plan criteria for change in pH, and percent reduction in clarity. Conversely, most discharge sites the passed the change in temperature criterion.

All lakes sites failed the total nitrogen (TN) criterion, and only Lake Koitiata passed the chlorophyll-*a* and total phosphorus (TP) criteria. Grades varied across the region for the *E. coli* (bathing) criteria. For estuary sites, all sites failed *E. coli* criteria and passed NH4-N criteria and for coastal sites, all sites based the NH4-N criteria and failed the TN, TP and enterococci (bathing) criteria.

There are no immediately obvious geographic patterns associated with the variation in grades, however this does not mean that there are not associations with, for example, river size or catchment land cover..

7.2 Water quality trends

Water quality trends for the 10 year period were assessed for up to 100 (of 112) river SoE sites, 27 (of 27) river impact sites, 24 (of 34) discharge sites, 4 (of 15) lake sites, 6 (of 7) estuary sites and 4 (of 4) coastal sites. Water quality trends for the 20 year period were assessed at up to 28 (of 112) river SoE sites and 2 (of 34) discharge sites. There were insufficient data to calculate 20 year trends at any Lake, Estuary, Coastal or river impact sites. Water quality trends for the 30 year period were also calculated for up to 6 river SoE sites. The difference in numbers of sites between time periods reflects the significant expansion of Horizon Regional Council's river monitoring network over the period 2007-2010, and the lake monitoring network in recent years.

For the 10 year period and river SoE site trends, seven of the 15 water quality variables had more than half of sites categorised as "likely degrading" or "Very likely degrading" (chlorophyll *a*, visual clarity, DRP, MCI, NH4-N, percent cover of mat algae and SIN), whereas only two variables had more than half of sites classes as "likely improving" or "very likely improving" (DO_Sat, sCBOD5). In previous trend assessments (and over the 20 year trend period) NH4-N was dominated by improving trends. However, the majority of the NH4-N trends are evaluated as having a Sen slope of zero (i.e., below the rate of detection given by the detection limit and time period).

7.3 Relationships between state and trends

For river and lake sites the trends with the largest rates of degradation trends were associated with sites with poor state grades, almost uniformly across all variables. For *E. coli*, the largest improving trend rates were at sites that had failed the One Plan *E.coli* criteria. At estuary sites, all but one site that failed the One Plan *E. coli* criteria had improving trends for *E. coli*. At both lakes and estuaries there was a pattern of larger degrading trend rates with larger (worse) water quality (based on compliance statistics). Trends in chlorophyll-*a* at coastal sites indicate improvement, both for sites that have passed and failed the One Plan chlorophyll-*a* criterion.

Acknowledgements

Thanks to Maree Patterson and Luke Fullard and the Catchment Data team of HRC for provision of data, site information, reviews, and advice of various types during the study.

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Appendix A Site specific One Plan criteria

Table 10: Site specific One Plan criteria for river (SoE and Impact) sites

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Arawhata drain at Hokio Beach Rd	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Hautapu River at Alabasters	120	5	0.01	0.11	80	120	0.4	2.1	3	260	550	60	30	1.5
Hautapu River at downstream of Taihape STP	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Hautapu River at Papakai Road Bridge	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Hautapu River upstream of the Rangitīkei River confluence	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Hokio Stream at Lake Horowhenua	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Kahuterawa River at Johnstons Rātā	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Kahuterawa River at Keebles Farm	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Kai Iwi Stream at Handley Road	200	5	0.015	0.167	70	100	0.4	2.1	1.6	260	550	60	30	2
Kaikōkopu Stream at Himatangi Beach	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Kaitoke Stream at Vector Gas Line	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Kiwitea Stream at Kimbolton Rd	120	5	0.01	0.167	70	120	0.4	2.1	2.5	260	550	60	30	2
Koitiata Stream at Beamish Rd	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Kōpūtaroa Stream at Tavistock Rd	200	5	0.015	0.444	60	100	0.4	2.1	2.5	260	550	60	30	2
Kuku Stream at N. Johnstone Farm Bridge	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Kūmeti Stream at Te Rehunga	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Mangaroa Stream at Lindsay Rd	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Makahika Stream above Ōhau Confluence	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mākākahi River downstream of Eketāhuna STP	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mākākahi River at end of Kaiparoro Road	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mākākahi River at Hāmua	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mākākahi River upstream of Eketāhuna STP	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Makaretu Stream above Ōhau Confluence	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Makomako Road drain at Lake Horowhenua	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Makorokio Stream at Tirohanga Station	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Makotuku River upstream of Raetihi STP	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Makotuku River downstream of Raetihi STP	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Makotuku River at Raetihi	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Makotuku River at State Highway 49A	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mākuri River at Tuscan Hills	120	5	0.01	0.11	80	120	0.4	2.1	3	260	550	60	30	1.5
Manakau Stream at Cemetery	120	5	0.01	0.167	70	100	0.4	2.1	2.1	260	550	60	30	2
Manakau Stream at SH1 Bridge	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River downstream of PNCC STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River downstream of Fonterra Longburn	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River at Hopelands	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Manawatū River at Ngāawapūrua Bridge	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Manawatū River at Ōpiki Bridge	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River at Teachers College	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River upstream of PNCC STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River at Upper Gorge	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River upstream of Fonterra Longburn	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Manawatū River at Weber Road	120	5	0.01	0.167	80	120	0.4	2.1	3	260	550	60	30	1.5
Manawatū River at Whirokino	200	5	0.015	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangaatua Stream downstream of Woodville STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangaatua Stream upstream of Woodville STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangaehuehu Stream downstream of Rangataua STP	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangaehuehu Stream upstream of Rangataua STP	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangahao River at Ballance	50	5	0.006	0.167	80	120	0.32	1.7	3	260	550	60	30	1.5
Manganui o te Ao River at Ruatiti Domain	120	5	0.01	0.11	80	120	0.32	1.7	3.4	260	550	60	30	1.5
Mangaore River downstream of Shannon STP	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangaore River upstream of Shannon STP	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangapapa Stream at Troup Rd	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangarangiora Stream downstream of Ormondville STP	120	5	0.01	0.167	80	120	0.4	2.1	3	260	550	60	30	1.5

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Mangarangiora Stream upstream of Ormondville STP	120	5	0.01	0.167	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangarangiora Stream tributary downstream of Norsewood STP	120	5	0.01	0.167	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangarangiora Stream tributary upstream of Norsewood STP	120	5	0.01	0.167	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River at SH2 Bridge	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River downstream of Pahiatua STP	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River at Hukanui	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River at Larsons Road	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangatainoka River at Pahiatua Town Bridge	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River at Pūtara	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangatainoka River at Scarborough Kōnini Rd	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River upstream of Pahiatua STP	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatainoka River upstream of Tīraumea confluence	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatepopo River at downstream Intake	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangatera River at downstream of Dannevirke STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangatera River at Dannevirke	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangatera River upstream of Manawatū confluence	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Mangatera River upstream of the T.D.C. oxidation ponds	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Mangatewainui River at Hardie's	120	5	0.01	0.167	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangatoro Stream at Mangahei Road	120	5	0.01	0.11	80	120	0.4	2.1	3	260	550	60	30	1.5
Mangawhero River downstream of Ohakune STP	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangawhero River at DOC Headquarters	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangawhero River at Pakihi Rd Bridge	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Mangawhero River at Raupiu Road	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Mangawhero River upstream of Ohakune STP	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Moawhango River at Waiouru	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Ngatahaka Stream upstream of Mākākahi confluence	120	5	0.01	0.444	80	120	0.4	2.1	3	260	550	60	30	1.5
Ōhau River at Gladstone Reserve	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Ōhau River at Haines Property	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōhau River at State Highway Bridge	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōhau River upstream of Makahika confluence	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Ōhura River at Tokorima	200	5	0.015	0.167	70	100	0.4	2.1	1.6	260	550	60	30	2
Ōngarue River at Taringamotu	120	5	0.01	0.11	80	100	0.4	2.1	2.5	260	550	60	30	1.5
Ōroua River at Almadale Slackline	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua River at Apiti Gorge Bridge	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua River at Awahuri Bridge	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua River downstream of AFFCO Feilding	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Ōroua River downstream of Feilding STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua River at Mangawhata	200	5	0.015	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua River upstream of AFFCO Feilding	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua River upstream of Feilding STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua tributary upstream of Kimbolton STP	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōroua tributary downstream of Kimbolton STP	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōruakeretaki Stream at downstream PPCS Oringi STP	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Ōruakeretaki Stream at SH2 Napier	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Owahanga River at Branscombe Bridge	200	5	0.015	0.167	70	100	0.4	2.1	1.6	260	550	60	30	2
Patiki Stream at Kawiu Road	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Piakatutu Stream downstream of Sanson STP	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Piakatutu Stream upstream of Sanson STP	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Pohangina River at Mais Reach	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Pohangina River at Piripiri	120	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Pongaroa River downstream of the Pongaroa STP	200	5	0.015	0.167	70	100	0.4	2.1	1.6	260	550	60	30	2
Pongaroa River upstream of the Pongaroa STP	200	5	0.015	0.167	70	100	0.4	2.1	1.6	260	550	60	30	2
Pōrewa Stream downstream of Hunterville STP Site	120	5	0.01	0.11	70	100	0.4	2.1	1.6	260	550	60	30	2
Pōrewa Stream downstream of Hunterville STP Site A	120	5	0.01	0.11	70	100	0.4	2.1	1.6	260	550	60	30	2
Pōrewa Stream at Onepuhi Road	120	5	0.006	0.07	70	120	0.32	1.7	3	260	550	60	30	2

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Pōrewa Stream upstream of Hunterville STP	120	5	0.01	0.11	70	100	0.4	2.1	1.6	260	550	60	30	2
Pōrewa Stream upstream of Hunterville STP Site A	120	5	0.01	0.11	70	100	0.4	2.1	1.6	260	550	60	30	2
Rangitawa Stream downstream of Halcombe oxidation pond	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Rangitawa Stream upstream of Halcombe oxidation pond	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Rangitīkei River downstream of Riverlands	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Rangitīkei River at Mangaweka	120	5	0.01	0.11	80	120	0.32	1.7	3.4	260	550	60	30	1.5
Rangitīkei River at McKelvies	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Rangitīkei River at Onepuhi	120	5	0.01	0.11	80	120	0.4	2.1	3	260	550	60	30	1.5
Rangitīkei River at Pukeokahu	50	5	0.006	0.07	80	120	0.32	1.7	3.4	260	550	60	30	1.5
Rangitīkei River upstream of Bulls STP	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Rangitīkei River upstream of Riverlands	120	5	0.01	0.11	70	100	0.4	2.1	2.5	260	550	60	30	2
Raparapawai Stream at Jackson Rd	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Tamaki River at Stephensons	120	5	0.01	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2
Tamaki River at Tamaki Reserve	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Tīraumea River at Ngāturi	120	5	0.01	0.444	70	100	0.4	2.1	2	260	550	60	30	2
Tīraumea River upstream of Manawatū confluence	120	5	0.01	0.444	70	100	0.4	2.1	2	260	550	60	30	2
Tokiahuru River at Junction	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Tokiahuru River at Karioi Domain Road	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550			1.5
Tokomaru River at Horseshoe bend	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Turakina River at O'Neill's Bridge	200	5	0.015	0.167	70	100	0.4	2.1	1.6	260	550	60	30	2
Turitea Stream at No1 Dairy Farm	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Tūtaenui Stream downstream of Marton STP	200	5	0.01	0.11	60	100	0.4	2.1	2.5	260	550	60	30	2
Tūtaenui Stream upstream of Marton STP	200	5	0.01	0.11	60	100	0.4	2.1	2.5	260	550	60	30	2
Unnamed tributary of Waipu Stream downstream of Rātana STP	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Unnamed tributary of Waipu Stream upstream of Rātana STP	200	5	0.015	0.167	60	100	0.4	2.1	2.5	260	550	60	30	2
Waikawa Stream at Huritini	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Waikawa Stream at North Manakau Rd	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Waikawa Stream upstream of Manakau confluence*	120	5	0.01	0.167	70	100	0.4	2.1	2.5	260	550	60	30	2
Waitangi Stream downstream of Waiouru STP	120	5	0.01	0.11	80	100	0.4	2.1	2.5	260	550	60	30	1.5
Waitangi Stream upstream of Waiouru STP	120	5	0.01	0.11	80	100	0.4	2.1	2.5	260	550	60	30	1.5
Whakapapa River at Footbridge	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Whangaehu River downstream of Winstone Pulp	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Whangaehu River at Kauangaroa	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Whangaehu River upstream of Winstone Pulp	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Whanganui River at Cherry Grove	120	5	0.01	0.11	80	100	0.4	2.1	2.5	260	550	60	30	1.5
Whanganui at Downstream Intake	50	5	0.006	0.07	80	120	0.32	1.7	3	260	550	60	30	1.5
Whanganui River at Pipiriki	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Whanganui River at Te Maire	120	5	0.01	0.11	80	100	0.4	2.1	2.5	260	550	60	30	1.5

Site Name	Chlorophyll-a	POM	DRP	SIN	DO (Sat)	MCI	MH4-N (mean)	NH4-N (mean)	Clarity	E. coli (bathing)	E. coli (year round)	Periphyton (mats)	Periphyton (filaments)	SCBOD5
Whanganui River at Te Rewa	120	5	0.01	0.11	70	100	0.4	2.1	2	260	550	60	30	2
Whanganui River at Wades Landing	120	5	0.01	0.11	80	100	0.4	2.1	2.5	260	550	60	30	1.5
Whitebait Creek at Edinburgh Terrace	200	5	0.015	0.444	70	100	0.4	2.1	2.5	260	550	60	30	2

Table 11: Site specific One Plan criteria for river discharge sites

Site Name	pH (change)	Temperature (change)	Clarity (change)	QMCI (change)
Pongaroa STP at 2nd oxpond waste	0.5	3	30	20
AFFCO Fielding at Industrial Waste water	0.5	3	30	20
Dannevirke STP at microfiltered oxpond	0.5	3	30	20
DB Breweries at Industrial wastewater	0.5	3	20	20
Eketāhuna STP at Secondary oxpond waste	0.5	3	20	20
Feilding STP at Secondary oxpond waste	0.5	3	30	20
Foxton STP at Secondary oxpond waste	0.5	3	30	20
Kimbolton STP at oxpond waste	0.5	3	30	20
Norsewood STP at oxpond waste	0.5	3	20	20
Ormondville STP at 2nd oxpond waste	0.5	3	20	20
Pahiatua STP at Tertiary oxpond waste	0.5	3	20	20
PNCC STP at Tertiary Treated Effluent	0.5	3	30	20
PPCS Ōringi STP at oxpond waste	0.5	3	30	20
Rongotea STP at Secondary oxpond waste	0.5	3	30	20
Shannon STP at oxpond waste	0.5	3	30	20
Tokomaru at oxpond waste	0.5	3	30	20
Woodville STP at Secondary oxpond waste	0.5	3	30	20
Bulls STP at Secondary oxpond waste	0.5	3	30	20
Halcombe at Secondary oxpond	0.5	3	30	20
Hunterville STP at Microfiltration Plant	0.5	3	30	20
Hunterville STP at Secondary oxpond	0.5	3	30	20
Marton STP at Rock filtered oxpond waste	0.5	3	30	20
Ōhakea STP at Effluent outfall	0.5	3	30	20
Rātana STP at Secondary oxpond waste	0.5	3	30	20
Riverlands at Industrial wastewater	0.5	3	30	20
Sanson STP at Secondary oxpond waste	0.5	3	30	20
Taihape STP at oxpond waste	0.5	3	30	20
Ōhakune STP at Secondary oxpond waste	0.5	2	20	20
Raetihi STP at Secondary oxpond waste	0.5	2	20	20
Rangataua STP at Secondary oxpond waste	0.5	2	20	20
Waiōuru STP at oxpond waste	0.5	2	30	20
Winstone Pulp WWTP at oxpond waste	0.5	2	20	20
National Park STP at Secondary oxpond	0.5	2	20	20
Taumarunui STP at Tertiary treated waste	0.5	2	30	20

Table 12: Site specific One Plan criteria for lake sites

Site Name	**Chlorophyll-a (mean)**	**Chlorophyll-a (max)**	**TP**	**TN**	**NH4-N (ph>8.5)**	**Clarity**	**E. coli (Bathing)**	**E. coli (non-bathing)**
Lake Alice	8	30	0.03	0.49	0.4	0.8	250	550
Lake Dudding (Composite)	5	15	0.02	0.37	0.4	2.8	250	550
Lake Heaton	8	30	0.03	0.49	0.4	0.8	250	550
Lake Herbert	8	30	0.03	0.49	0.4	0.8	250	550
Lake Koitiata	8	30	0.03	0.49	0.4	0.8	250	550
Lake Koputara	8	30	0.03	0.49	0.4	0.8	250	550
Lake Waipū	5	15	0.02	0.37	0.4	2.8	250	550
Lake William	8	30	0.03	0.49	0.4	0.8	250	550
Omanuka Lagoon	8	30	0.03	0.49	0.4	0.8	250	550
Pukepuke Lagoon	8	30	0.03	0.49	0.4	0.8	250	550
Lake Horowhenua at Buoy	8	30	0.03	0.49	0.4	0.8	250	550
Lake Kohata	8	30	0.03	0.49	0.4	0.8	250	550
Lake Pauri (Composite)	5	15	0.02	0.37	0.4	2.8	250	550
Lake Westmere	8	30	0.03	0.49	0.4	0.8	250	550
Lake Wiritoa (Composite)	5	15	0.02	0.37	0.4	2.8	250	550

Table 13: Site specific One Plan criteria for estuary sites

Site Name	Chlorophyll-a	Temperature	DO (Sat)	DRP	SIN	NH4-N	E. coli (Bathing)	E. coli (year round)	Clarity
Ākitio Estuary at Coast Rd Bridge	4	22	70	0.015	0.167	0.4	260	550	1.2
Mōwhānau Stream at Footbridge	4	24	70	0.015	0.167	0.4	260	550	1.2
Manawatū at Foxton	4	24	70	0.015	0.444	0.4	260	550	1.2
Rangitīkei Estuary at River mouth	4	24	70	0.015	0.167	0.4	260	550	1.2
Ōhau at Estuary	4	22	70	0.01	0.11	0.4	260	550	1.2
Waikawa Estuary at Footbridge	4	22	70	0.01	0.167	0.4	260	550	1.2
Whanganui Estuary at Wharf St Boat Ramp	4	24	70	0.015	0.167	0.4	260	550	1.2

Table 14: Site specific One Plan criteria for coastal sites

Site Name	Chlorophyll-a	TP	TN	NH4-N	Enterococci (bathing)	Enterococci (non-bathing)	Faecal Coliforms (median)	Faecal Coliforms (q90)
Ākitio Beach at Surf Club	3	0.01	0.06	0.06	140	280	14	43
Himatangi Beach at Surf Beach	3	0.01	0.06	0.06	140	280	14	43
Kai Iwi Beach at Kai Iwi Stream Bridge	3	0.01	0.06	0.06	140	280	14	43
Waitarere Beach at Waitarere Surf Beach	3	0.01	0.06	0.06	140	280	14	43

Appendix B Monitoring site supplementary information

Table 15: Summary of discharge sites and associated up and downstream monitoring sites

Site Name	Relevant Impact Site	Relevant SOE Site	Relevant Impact Site MCI	Relevant SOE Site MCI
Pongaroa STP at 2nd oxpond waste	Pongaroa River downstream of the Pongaroa STP	Pongaroa River upstream of the Pongaroa STP		
AFFCO Fielding at Industrial Waste water	Ōroua River downstream of AFFCO Feilding	Ōroua River upstream of AFFCO Feilding		
Dannevirke STP at microfiltered oxpond	Mangatera River at downstream of Dannevirke STP	Mangatera River upstream of the T.D.C. oxidation ponds	Mangatera at d/s Dannevirke STP	Mangatera at u/s T.D.C. Ox Ponds
DB Breweries at Industrial wastewater	Mangatainoka River at SH2 Bridge	Mangatainoka River at SH2 Bridge	Mangatainoka at d/s DB Breweries	Mangatainoka at Brewery - S.H.2 Bridge
Eketāhuna STP at Secondary oxpond waste	Mākākahi River downstream of Eketāhuna STP	Mākākahi River upstream of Eketāhuna STP	Mākākahi at d/s Eketāhuna STP	Mākākahi at u/s Eketāhuna STP
Feilding STP at Secondary oxpond waste	Ōroua River downstream of Feilding STP	Ōroua River upstream of Feilding STP	Oroua at d/s Feilding STP	Oroua at U/S Feilding STP
Foxton STP at Secondary oxpond waste	NA	NA		
Kimbolton STP at oxpond waste	Ōroua tributary downstream of Kimbolton STP	Ōroua tributary upstream of Kimbolton STP		
Norsewood STP at oxpond waste	Mangarangiora Stream tributary downstream of Norsewood STP	Mangarangiora Stream tributary upstream of Norsewood STP		
Ormondville STP at 2nd oxpond waste	Mangarangiora Stream downstream of Ormondville STP	Mangarangiora Stream upstream of Ormondville STP		
Pahiatua STP at Tertiary oxpond waste	Mangatainoka River downstream of Pahiatua STP	Mangatainoka River upstream of Pahiatua STP	Mangatainoka at d/s Pahiatua STP	Mangatainoka at u/s Pahiatua STP
PNCC STP at Tertiary Treated Effluent	Manawatū River downstream of PNCC STP	Manawatū River upstream of PNCC STP	Manawatū at d/s PNCC STP	Manawatū at u/s PNCC STP
PPCS Ōringi STP at oxpond waste	Ōruakeretaki Stream at downstream PPCS Oringi STP	Ōruakeretaki Stream at SH2 Napier		
Rongotea STP at Secondary oxpond waste	NA	NA		
Shannon STP at oxpond waste	Mangaore River downstream of Shannon STP	Mangaore River upstream of Shannon STP		
Tokomaru at oxpond waste	NA	NA		
Woodville STP at Secondary oxpond waste	Mangaatua Stream downstream of Woodville STP	Mangaatua Stream upstream of Woodville STP	Mangaatua at d/s Woodville STP	Mangaatua at u/s Woodville STP

Bulls STP at Secondary oxpond waste	Rangitīkei River upstream of Riverlands	Rangitīkei River upstream of Bulls STP		
Halcombe at Secondary oxpond	Rangitawa Stream downstream of Halcombe oxidation pond	Rangitawa Stream upstream of Halcombe oxidation pond		
Hunterville STP at Microfiltration Plant	Pōrewa Stream downstream of Hunterville STP Site A	Pōrewa Stream upstream of Hunterville STP Site A	Pōrewa at d/s Hunterville STP	Pōrewa at u/s Hunterville STP
Hunterville STP at Secondary oxpond	Pōrewa Stream downstream of Hunterville STP Site A	Pōrewa Stream upstream of Hunterville STP	Pōrewa at d/s Hunterville STP	
Marton STP at Rock filtered oxpond waste	Tūtaenui Stream downstream of Marton STP	Tūtaenui Stream upstream of Marton STP		Tūtaenui Stream at Curls Bridge
Ōhakea STP at Effluent outfall	NA	NA		
Rātana STP at Secondary oxpond waste	Unnamed tributary of Waipu Stream downstream of Rātana STP	Unnamed tributary of Waipu Stream upstream of Rātana STP		
Riverlands at Industrial wastewater	Rangitīkei River downstream of Riverlands	Rangitīkei River upstream of Riverlands		
Sanson STP at Secondary oxpond waste	Piakatutu Stream downstream of Sanson STP	Piakatutu Stream upstream of Sanson STP		
Taihape STP at oxpond waste	Hautapu River at downstream of Taihape STP	Hautapu River at Papakai Road Bridge		Hautapu at Alabasters
Ōhakune STP at Secondary oxpond waste	Mangawhero River downstream of Ohakune STP	Mangawhero River upstream of Ohakune STP	Mangawhero at d/s Ohakune STP	Mangawhero at u/s Ohakune STP
Raetihi STP at Secondary oxpond waste	Makotuku River downstream of Raetihi STP	Makotuku River upstream of Raetihi STP	Makotuku at d/s Raetihi STP	Makotuku at Above Sewage Plant
Rangataua STP at Secondary oxpond waste	Mangaehuehu Stream downstream of Rangataua STP	Mangaehuehu Stream upstream of Rangataua STP		
Waiōuru STP at oxpond waste	Waitangi Stream downstream of Waiouru STP	Waitangi Stream upstream of Waiouru STP	Waitangi at d/s Waiouru STP	Waitangi at u/s Waiouru STP
Winstone Pulp WWTP at oxpond waste	Whangaehu River downstream of Winstone Pulp	Whangaehu River upstream of Winstone Pulp		
National Park STP at Secondary oxpond	NA	NA		
Taumarunui STP at Tertiary treated waste	Whanganui River at Cherry Grove	Whanganui River at Te Rewa		

Appendix C State with time

This appendix presents the results of the rolling state assessments, as described in section 3.1.3. Rolling state assessments are only shown for sites that had sufficient data to calculate rolling grades for five assessment periods (each of which is 5 years in duration).

C1 River SoE sites

C1.1 Chlorophyll-a

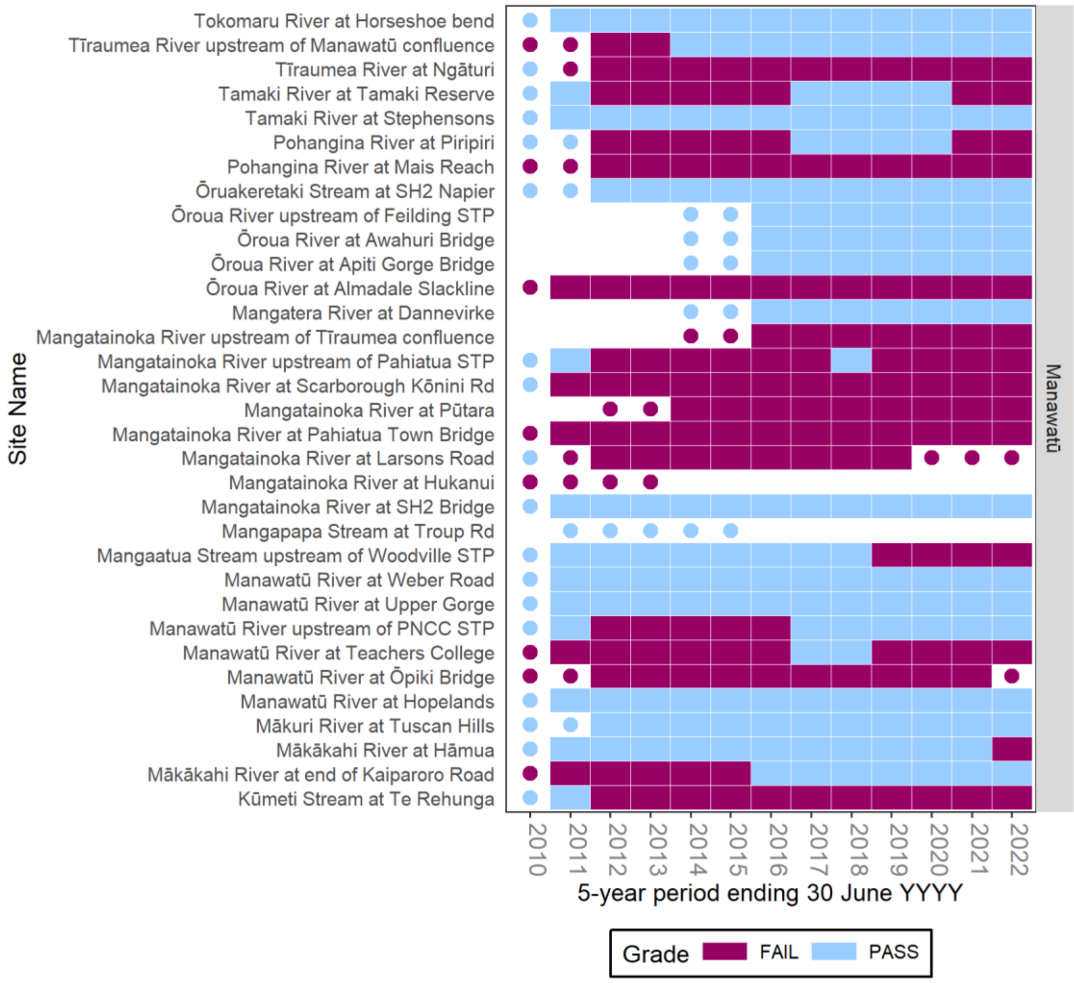

Figure 40: Rolling state assessment for One Plan river chlorophyll-a target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

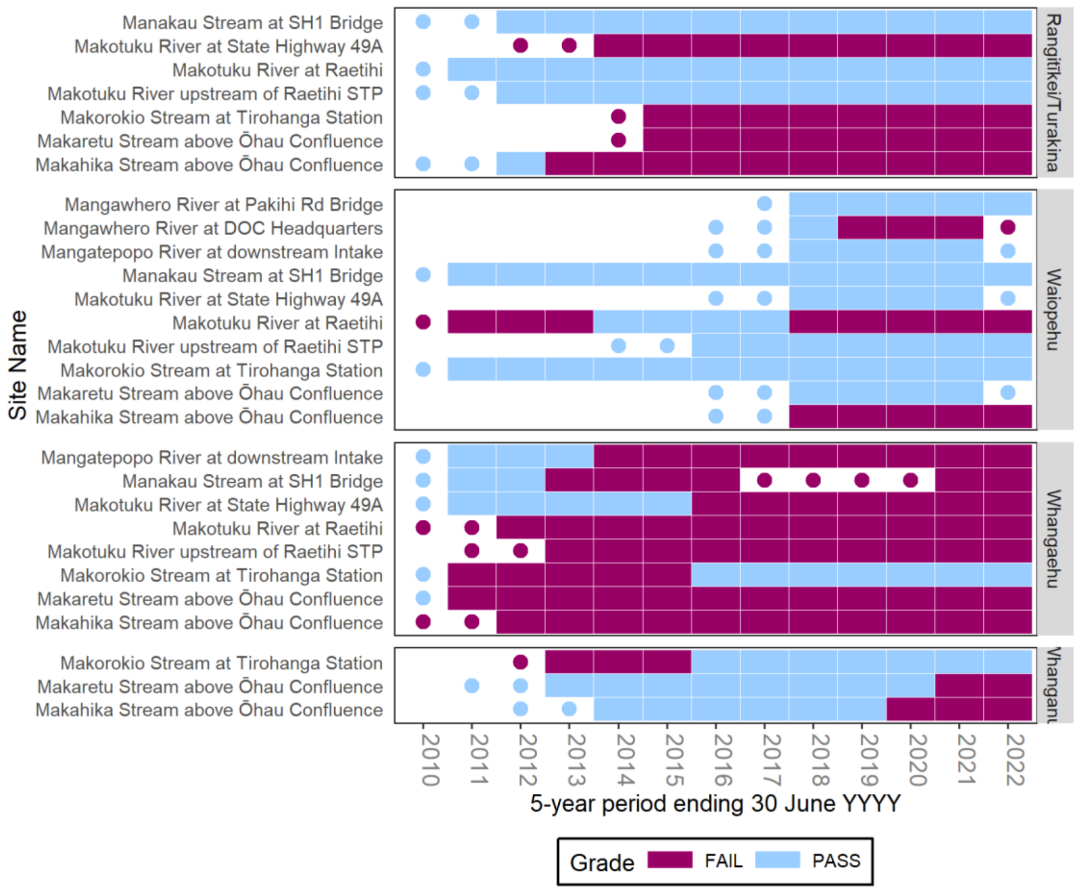

Figure 41: Rolling state assessment for One Plan river chlorophyll-a target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.2 Clarity

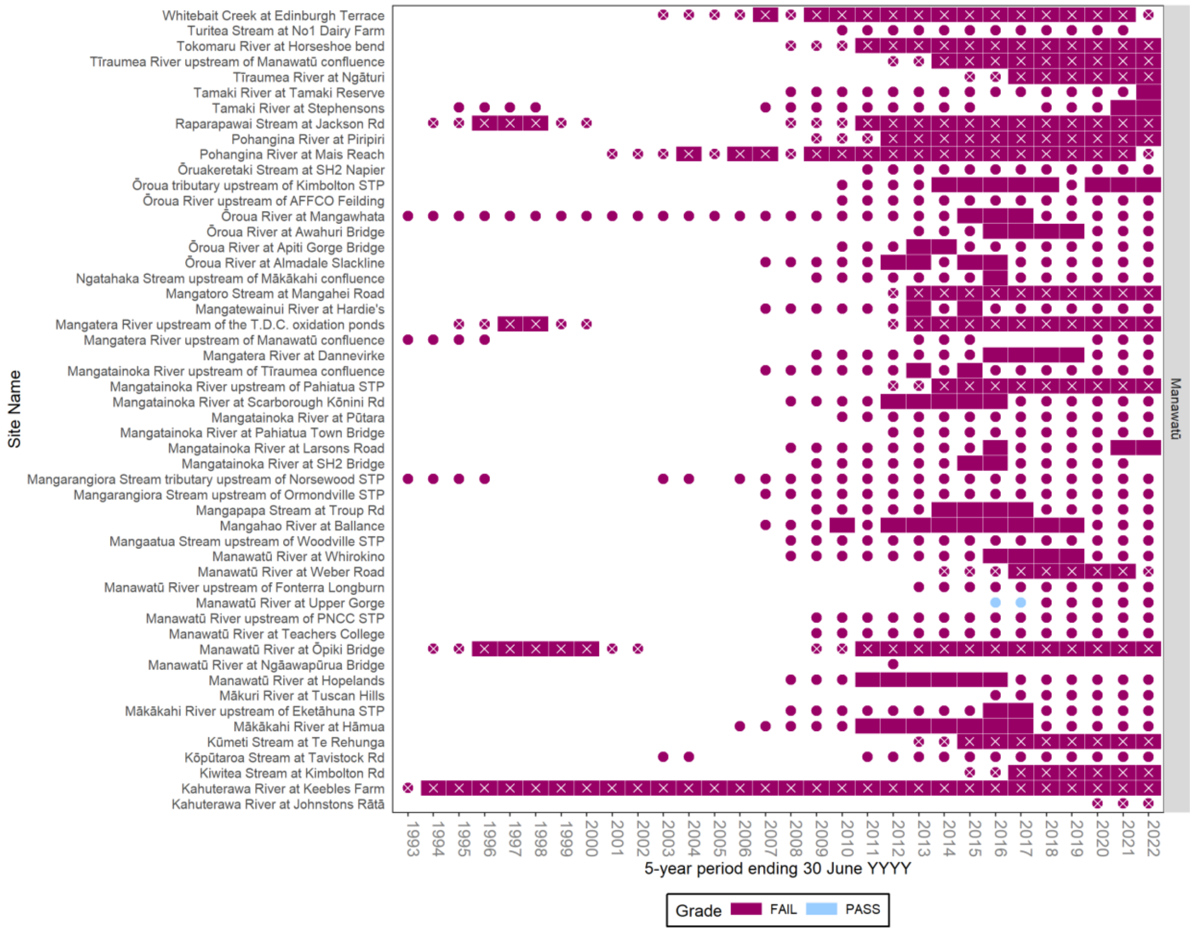

Figure 42: Rolling state assessment for One Plan river clarity target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

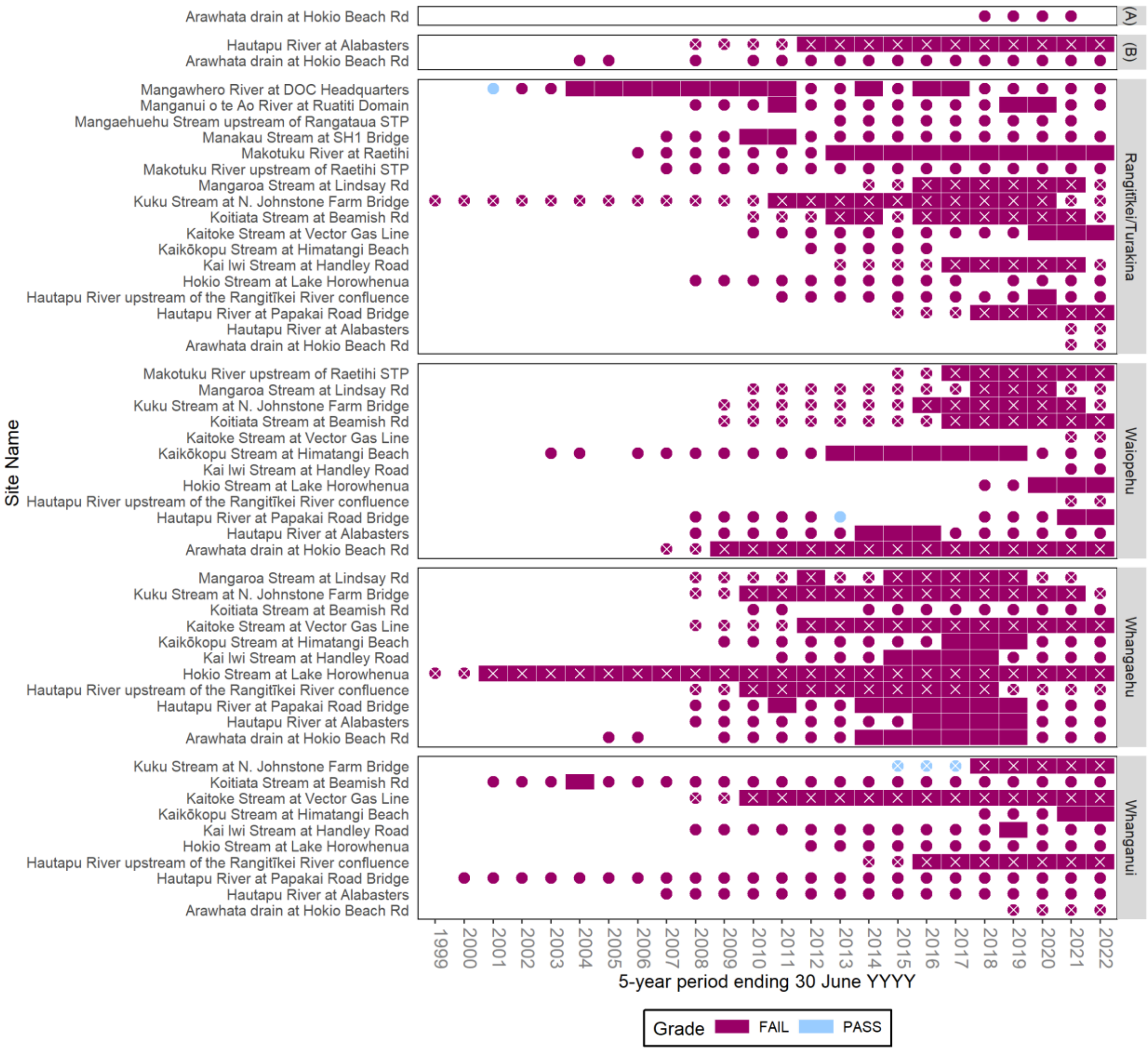

Figure 43: Rolling state assessment for One Plan river clarity target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C1.3 DO (Sat)

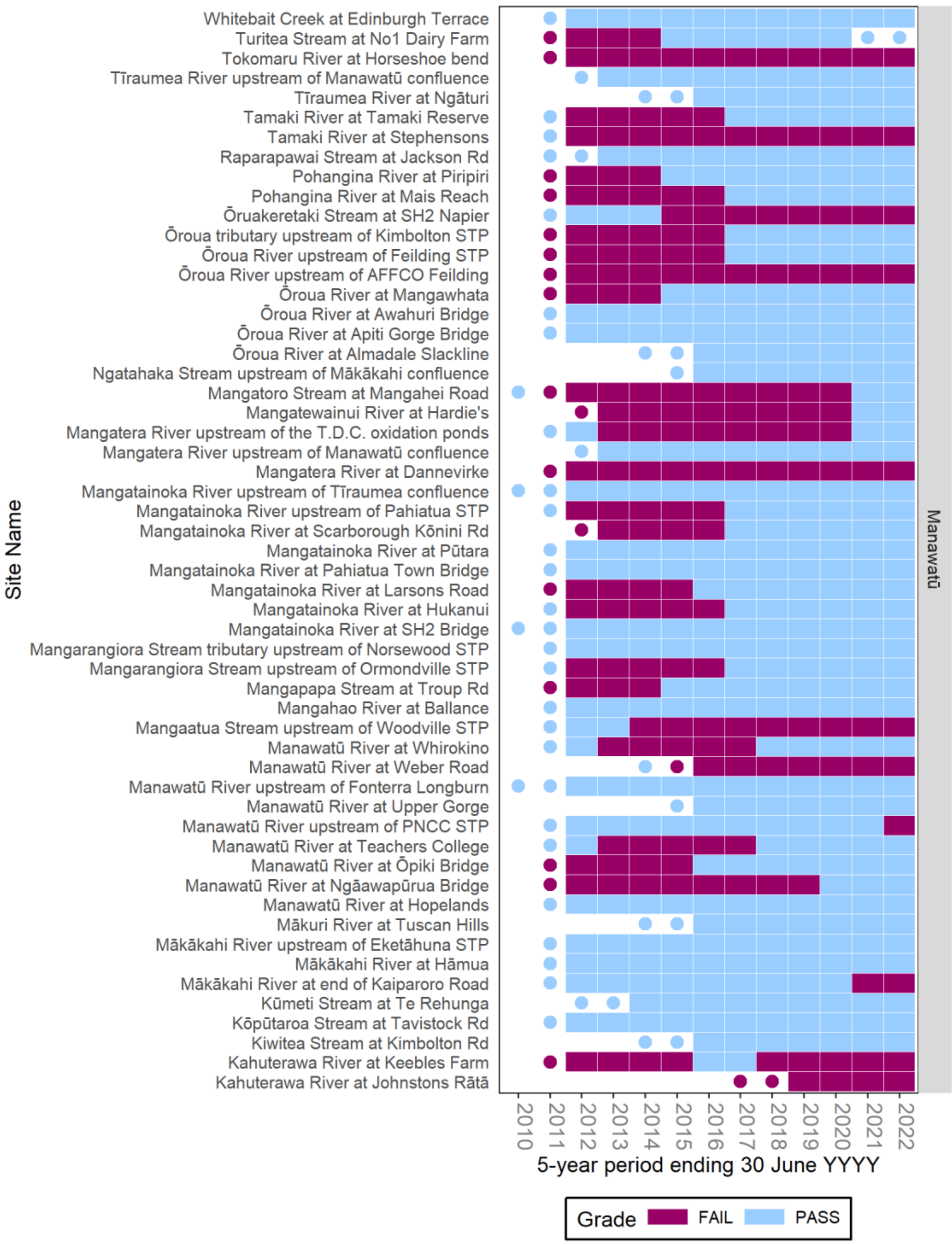

Figure 44: Rolling state assessment for One Plan river DO (sat) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

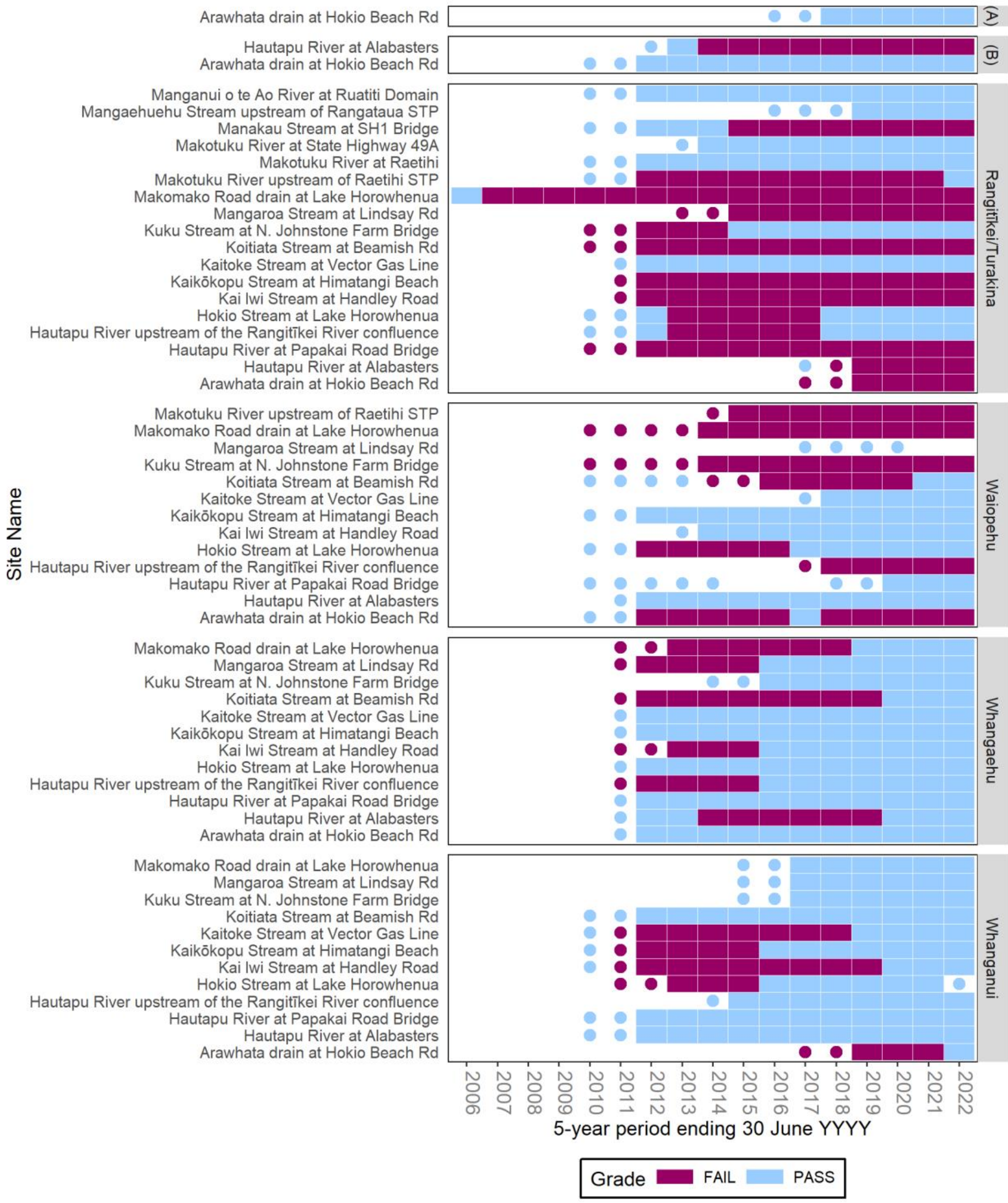

Figure 45: Rolling state assessment for One Plan river DO (sat) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.4 DRP

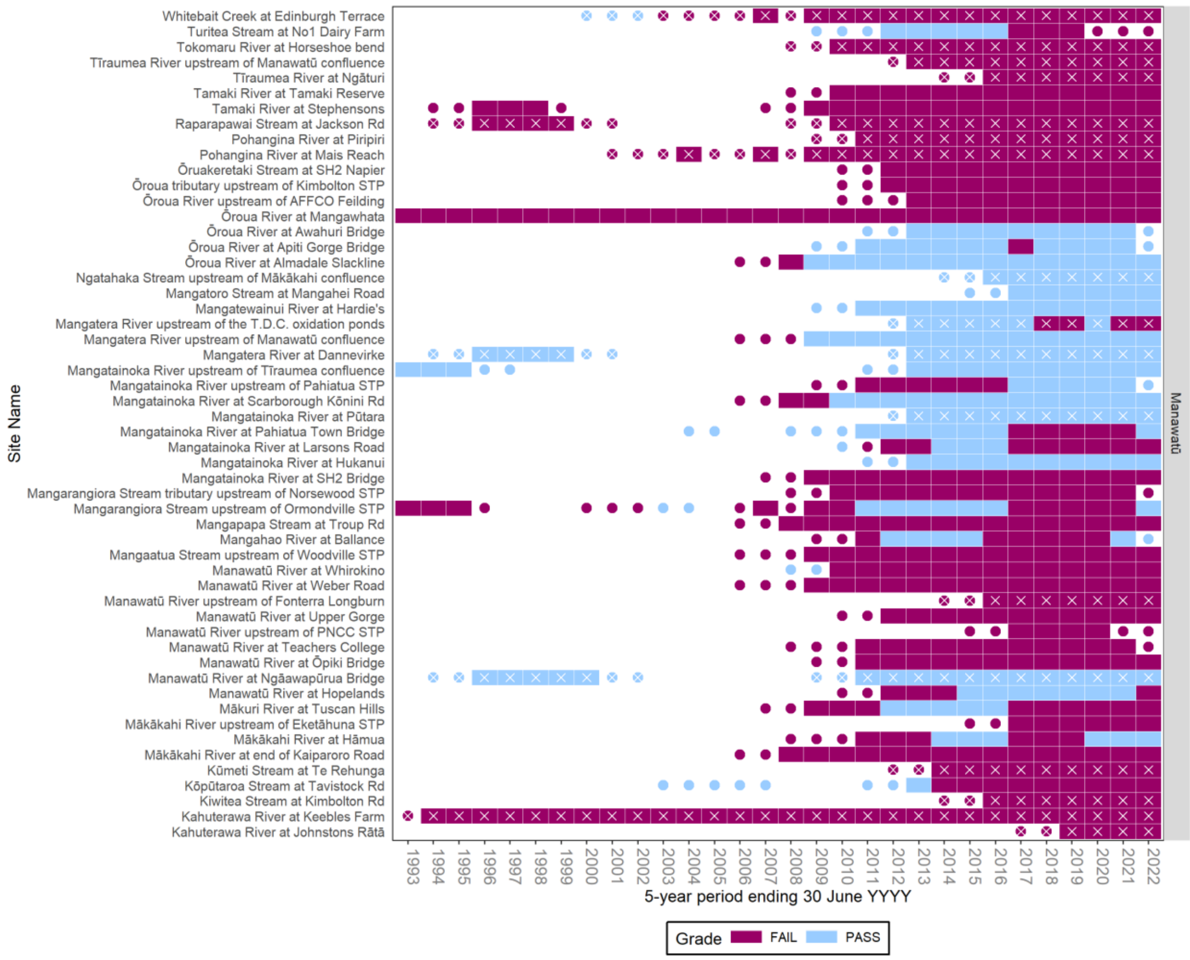

Figure 46: Rolling state assessment for One Plan river DRP target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

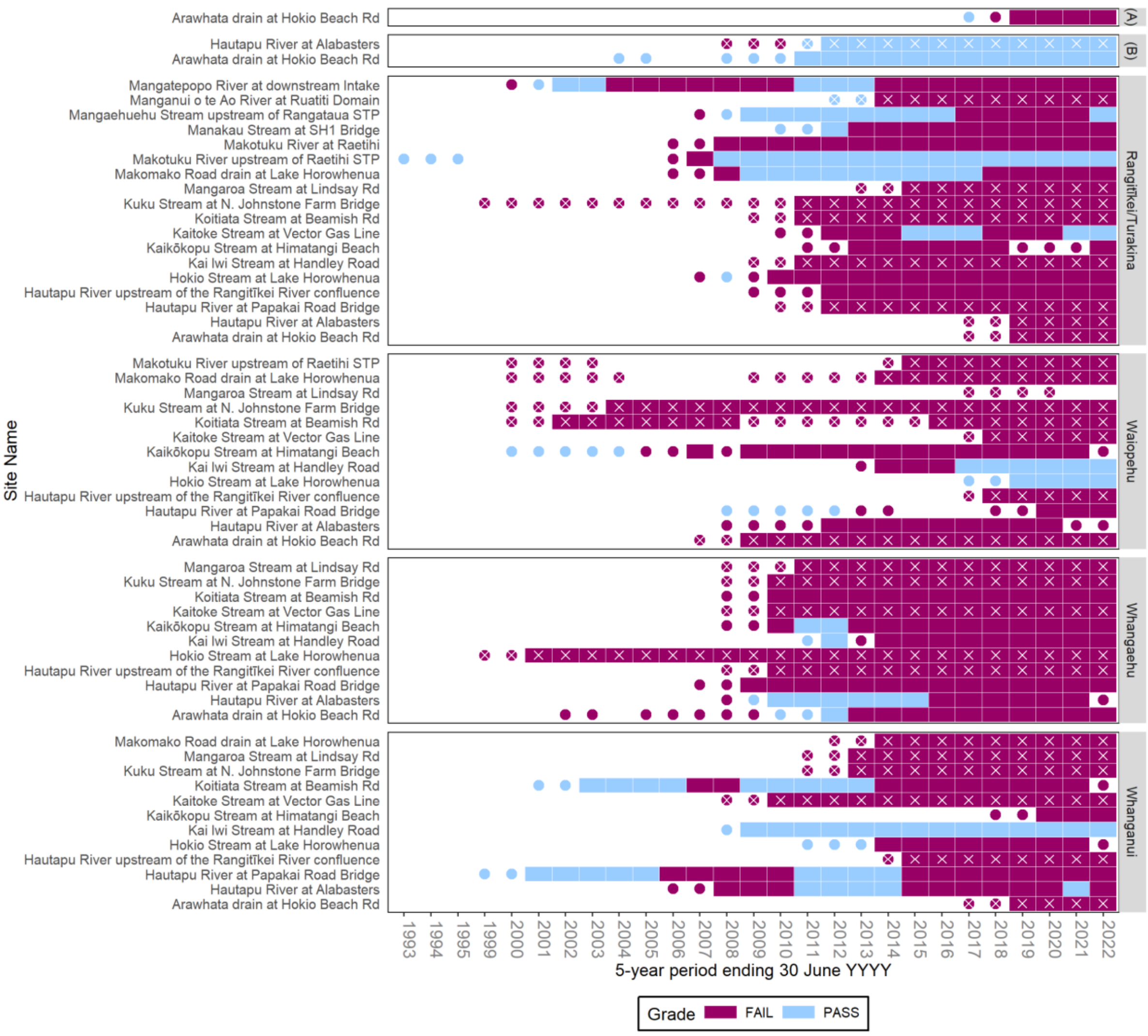

Figure 47: Rolling state assessment for One Plan river DRP target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C1.5 E. coli (bathing)

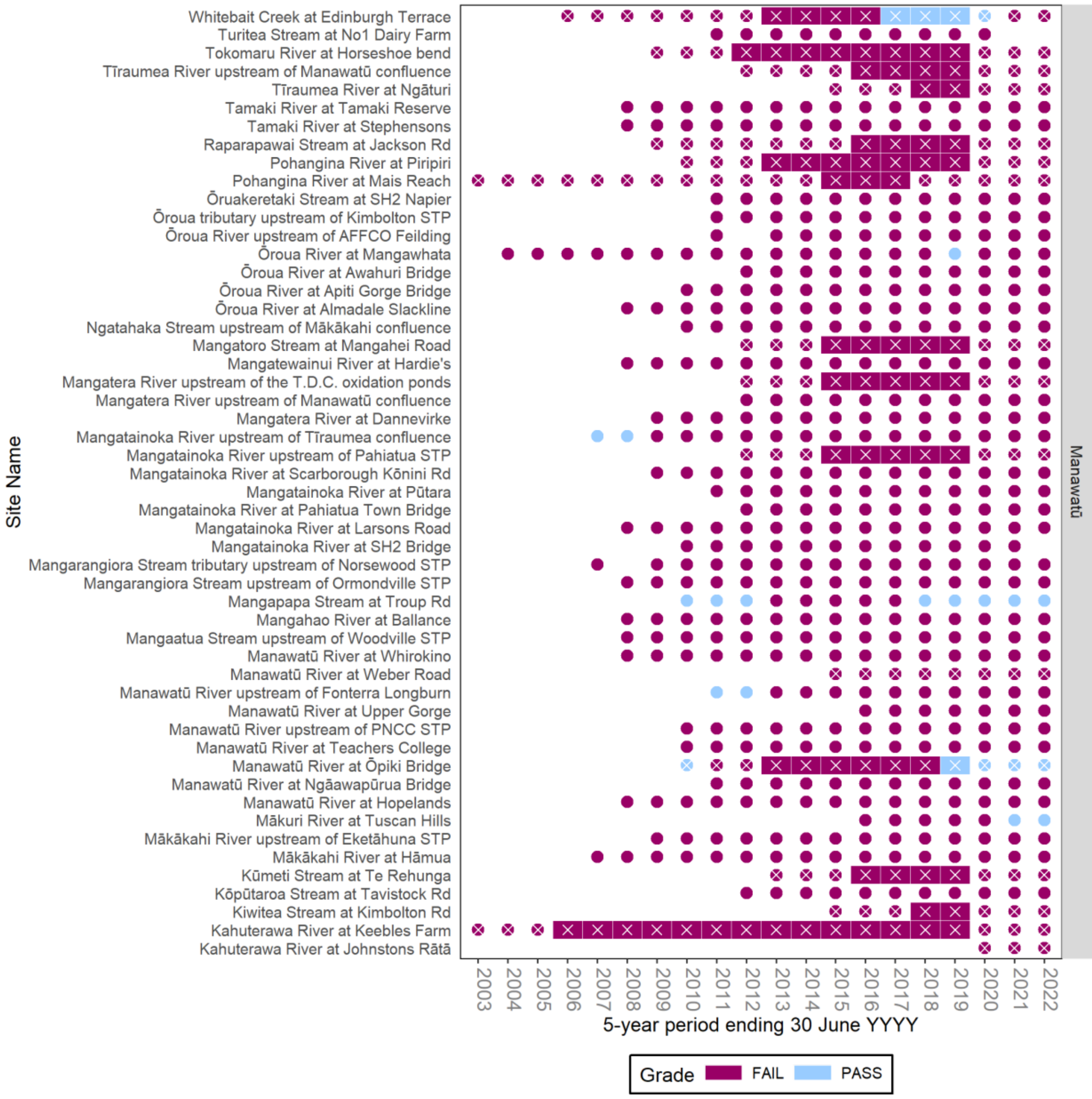

Figure 48: Rolling state assessment for One Plan river E. coli (bathing) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

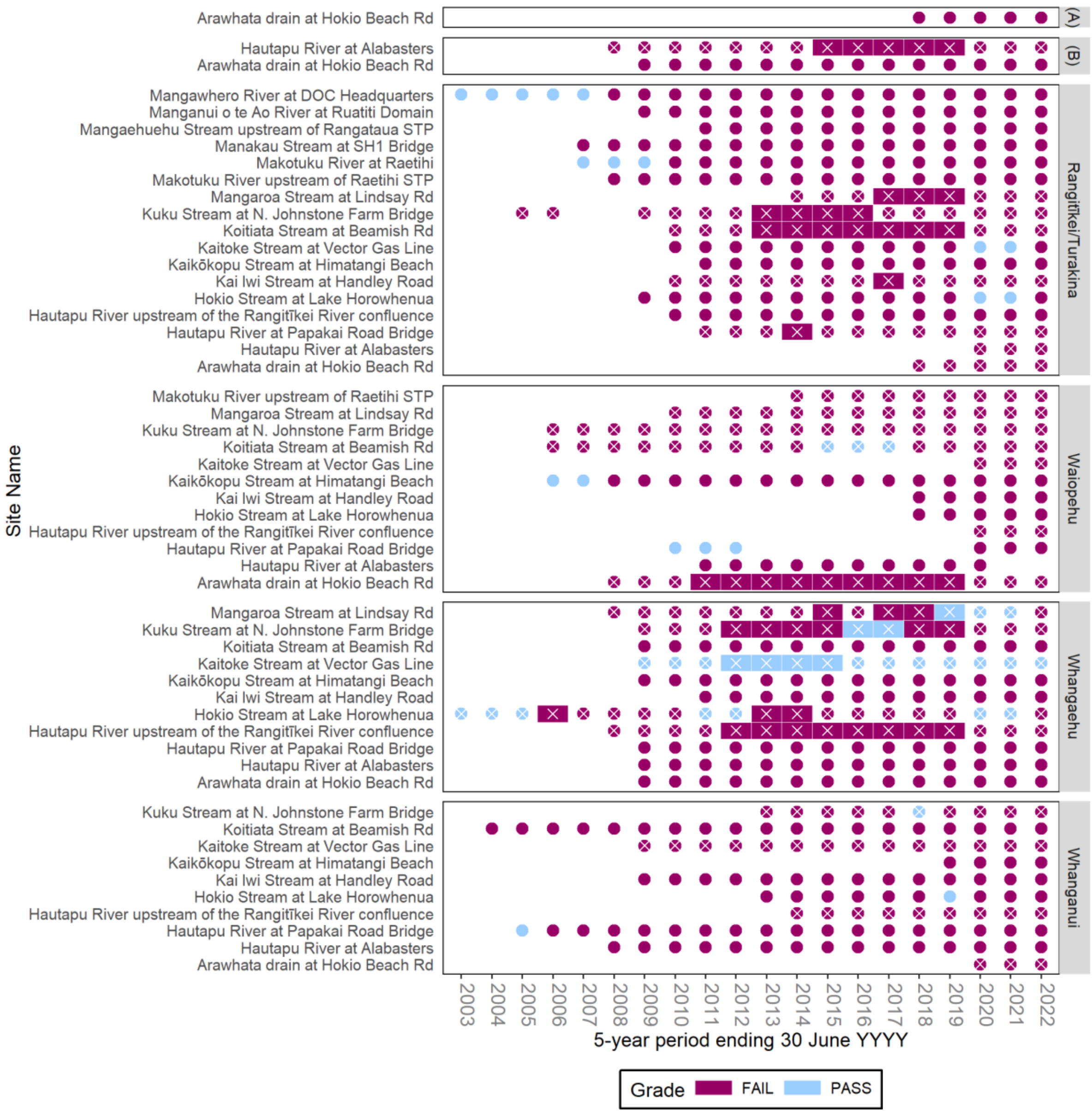

Figure 49: Rolling state assessment for One Plan river E. coli (bathing) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C1.6 E. coli (year round)

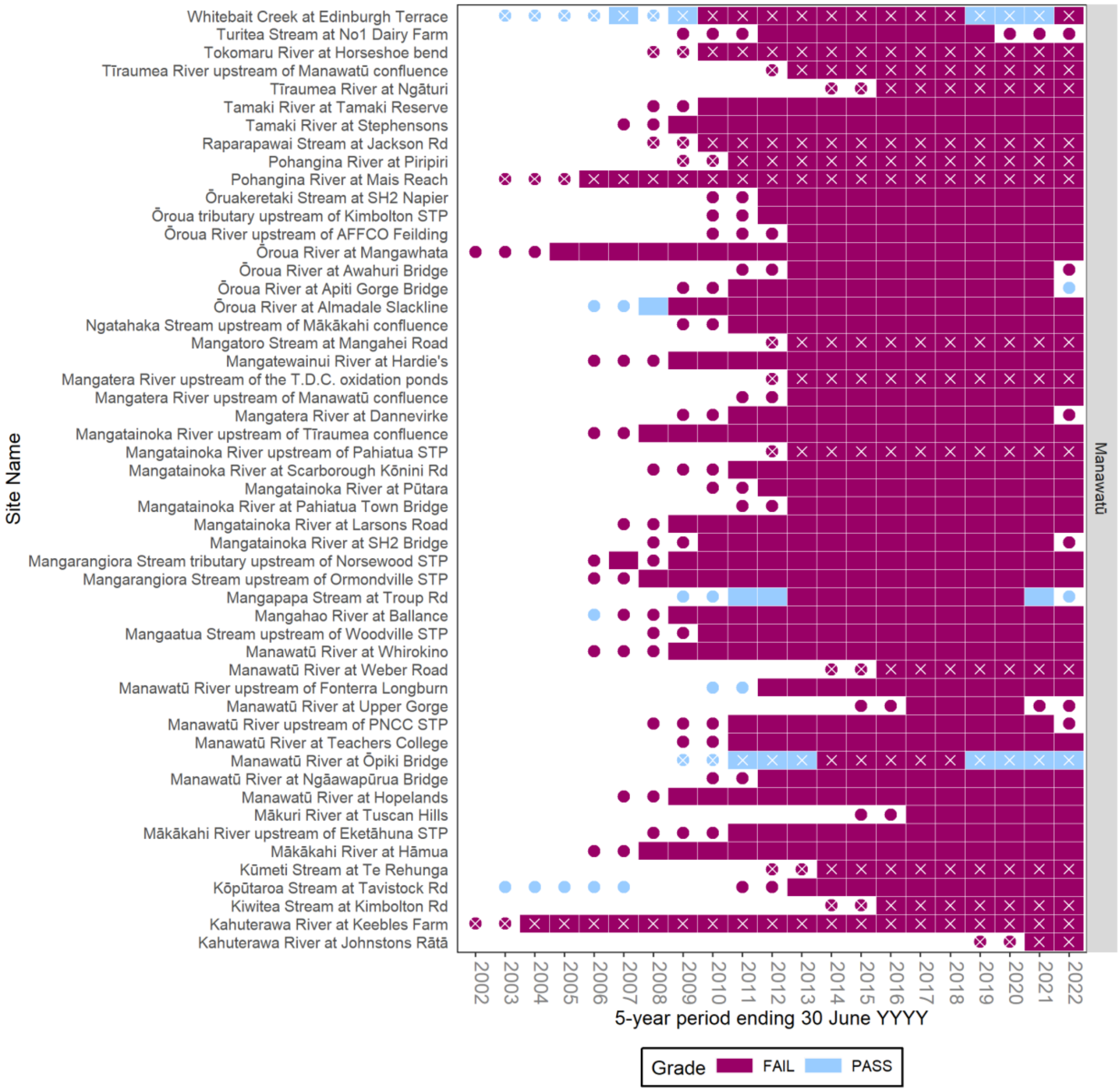

Figure 50: Rolling state assessment for One Plan river E. coli (year round) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

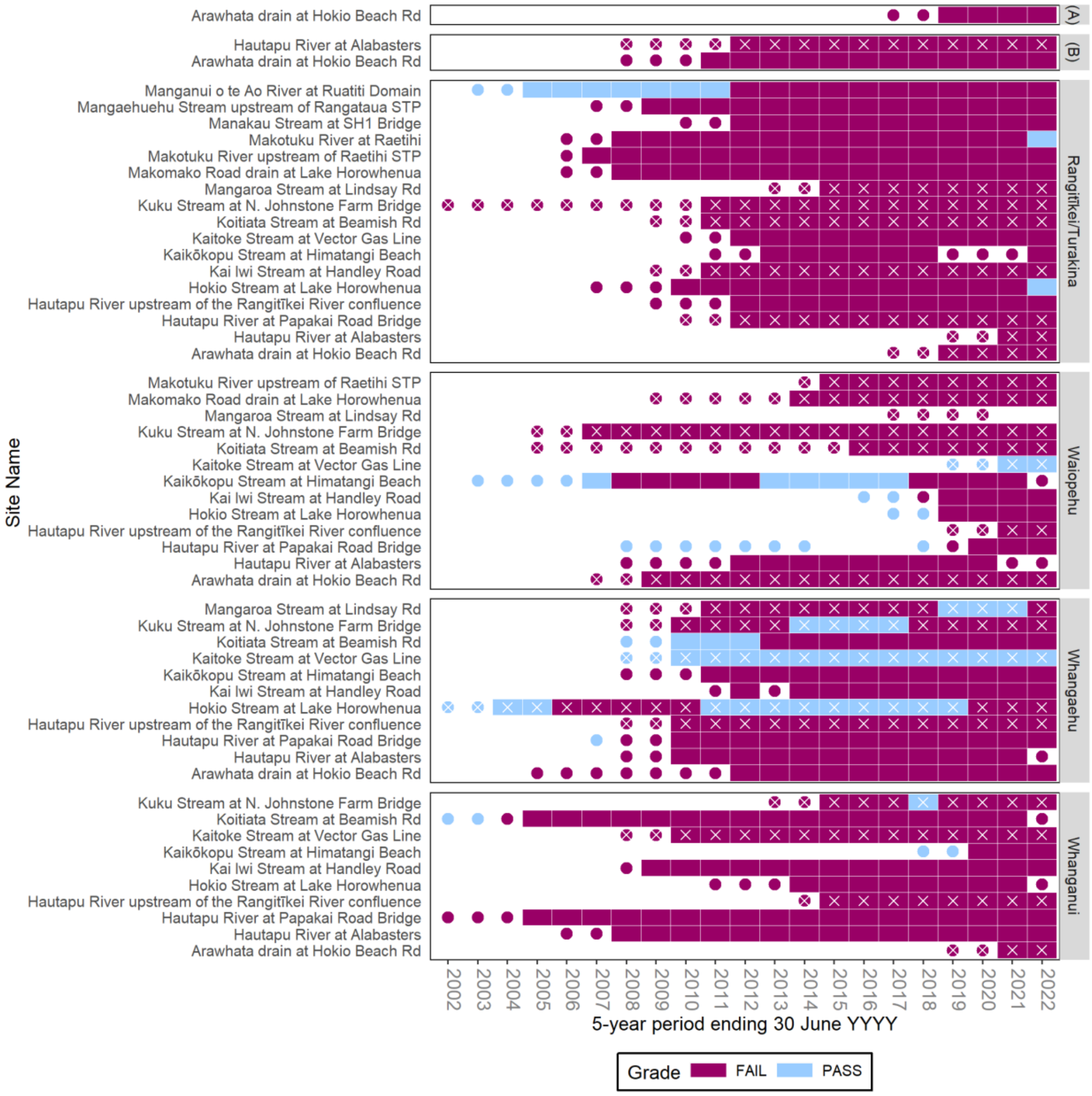

Figure 51: Rolling state assessment for One Plan river E. coli (year round) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C1.7 MCI

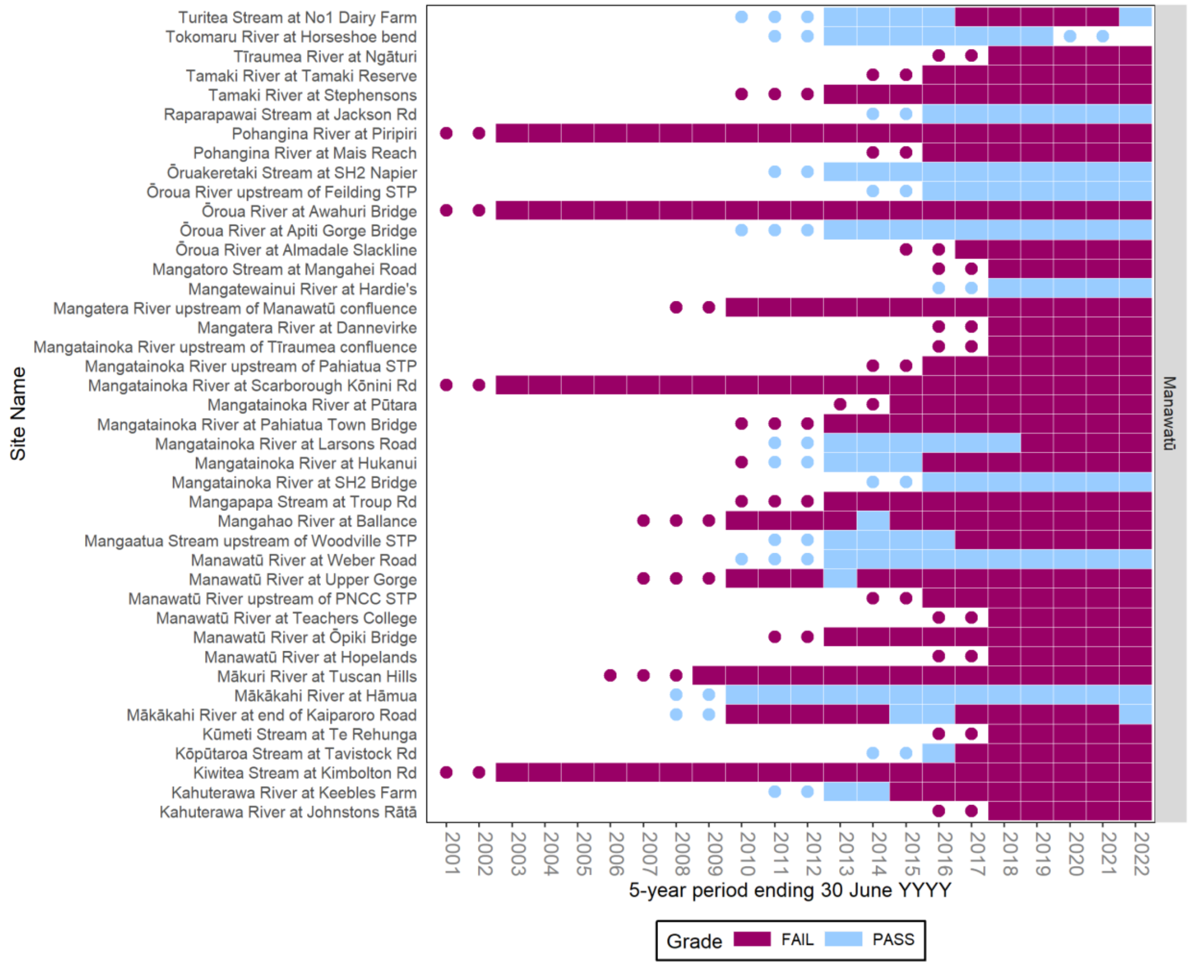

Figure 52: Rolling state assessment for One Plan river MCI target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

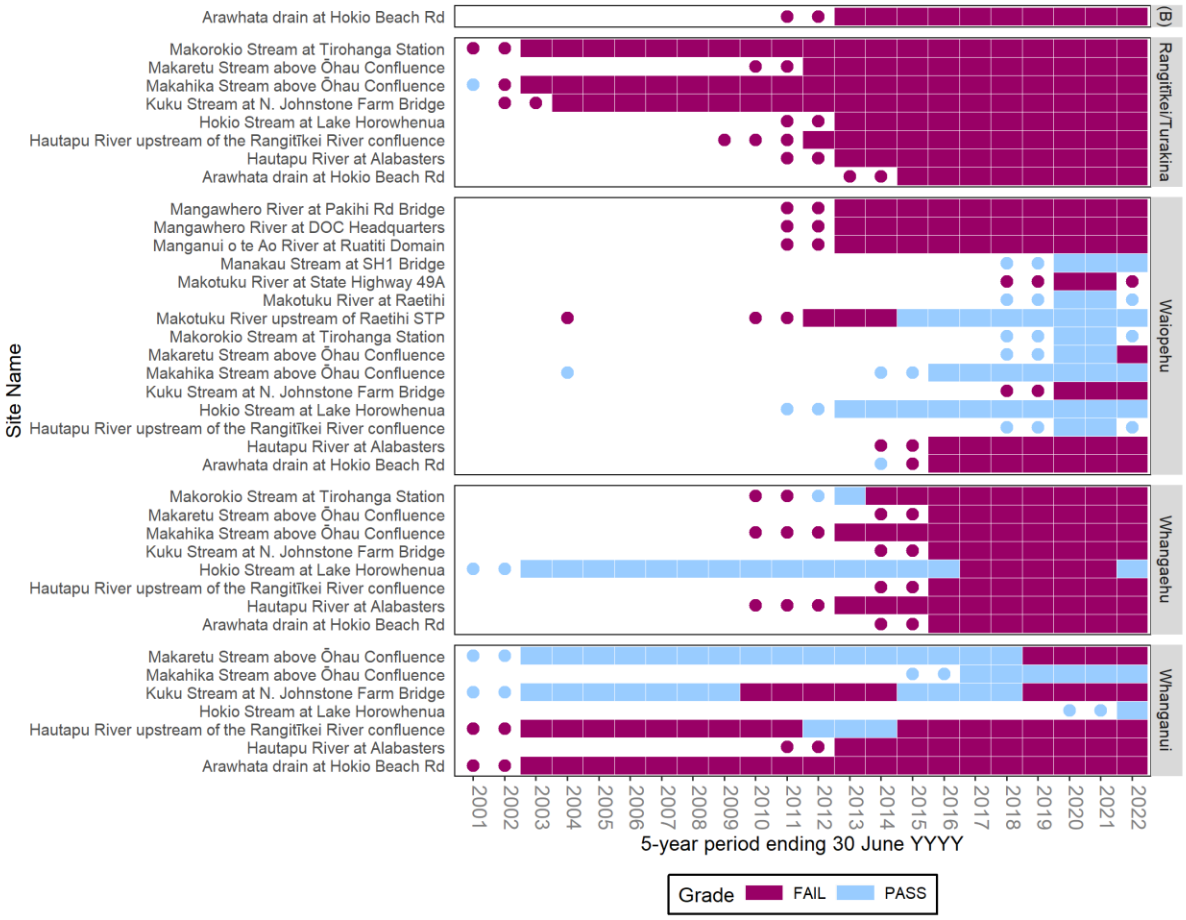

Figure 53: Rolling state assessment for One Plan river MCI target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.8 NH4-N (max)

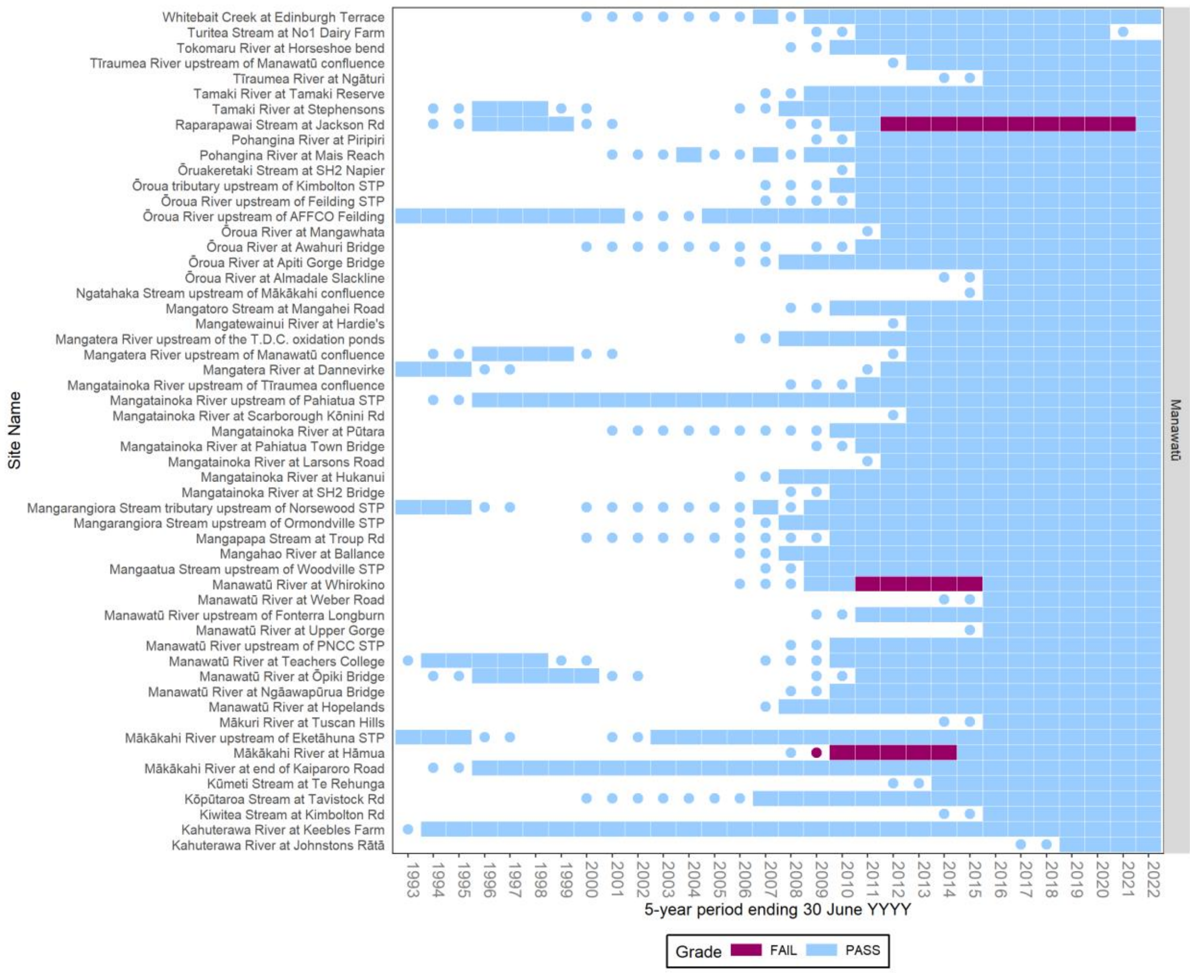

Figure 54: Rolling state assessment for One Plan river NH4-N (max) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

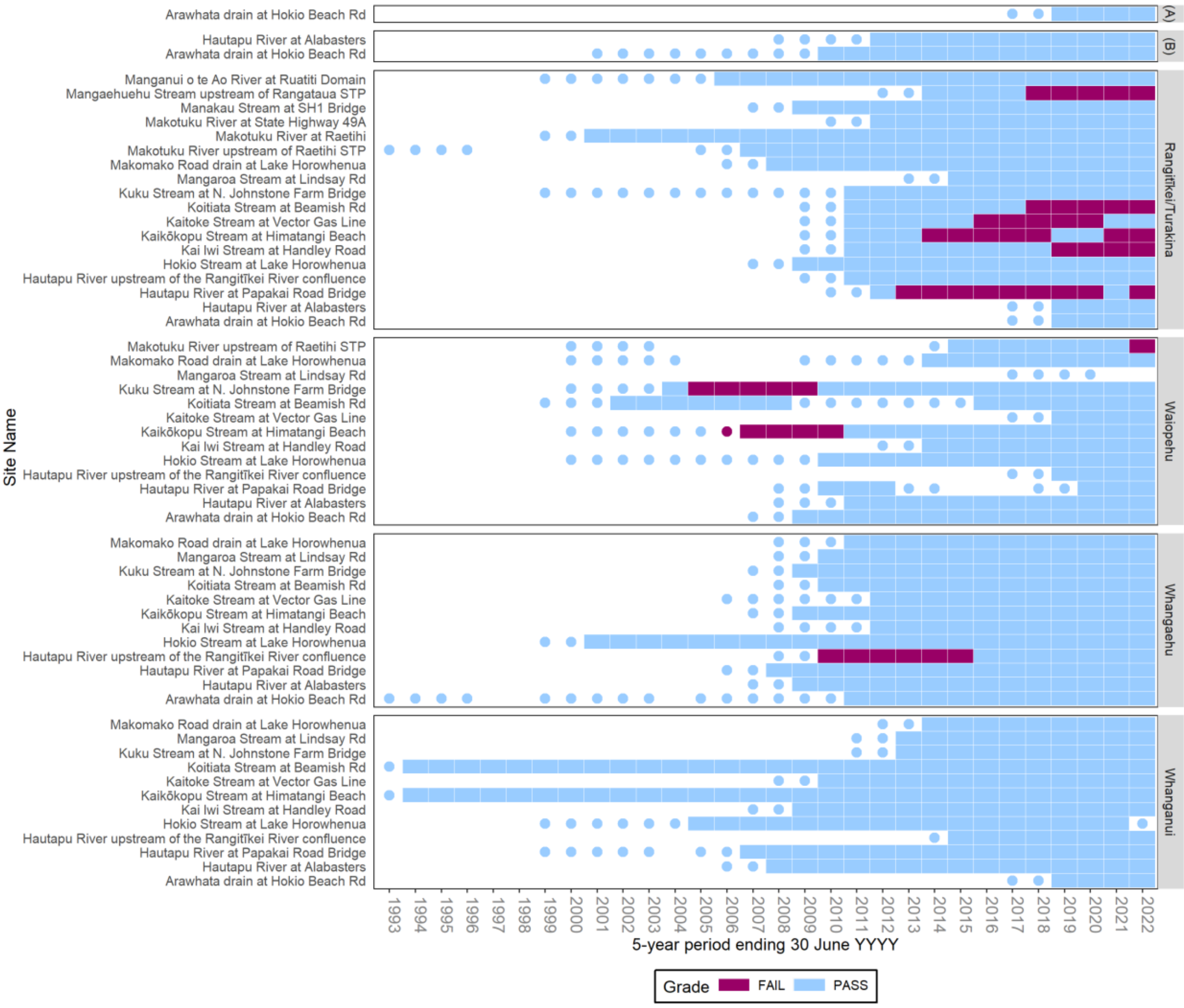

Figure 55: Rolling state assessment for One Plan river NH4-N (max) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.9 NH4-N (mean)

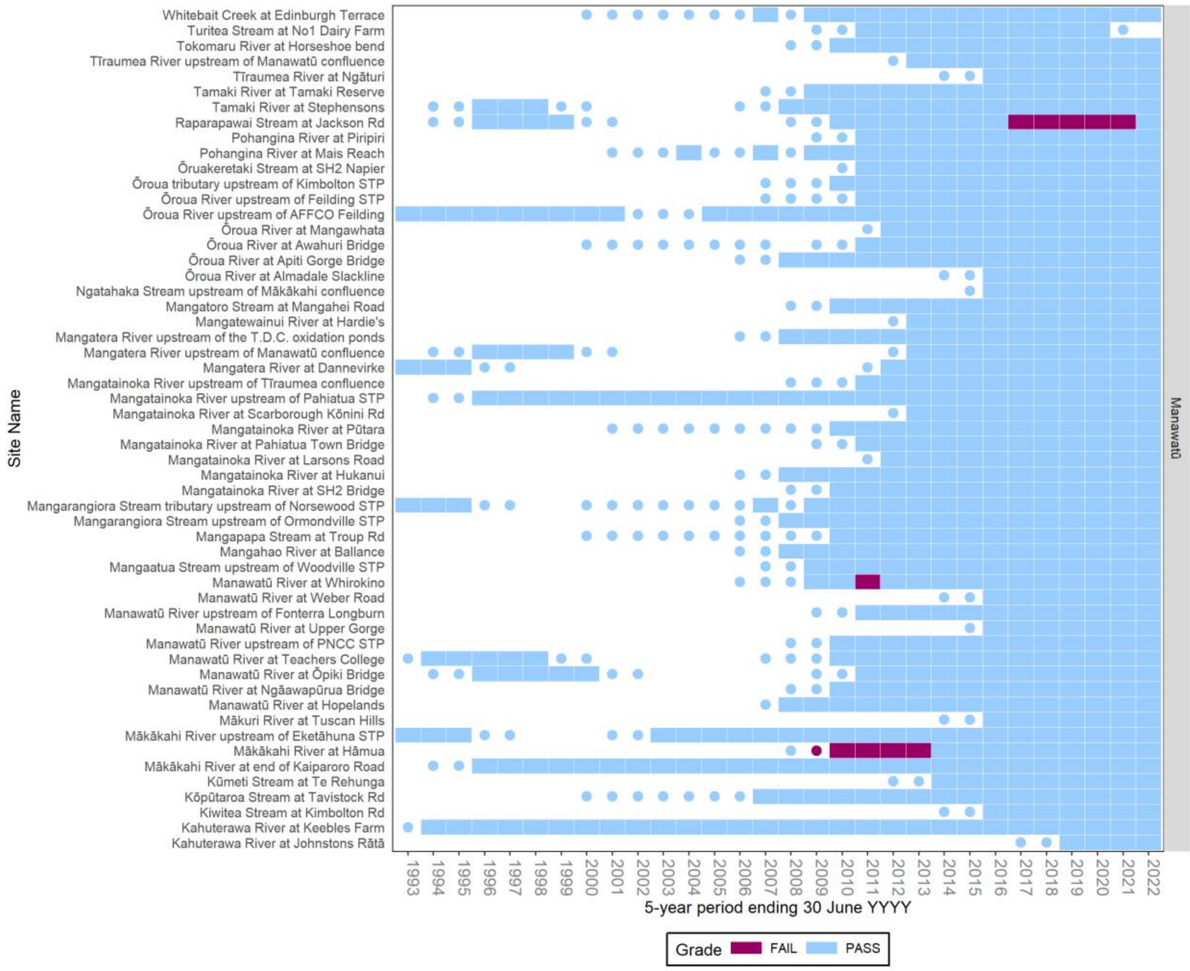

Figure 56: Rolling state assessment for One Plan river NH4-N (mean) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

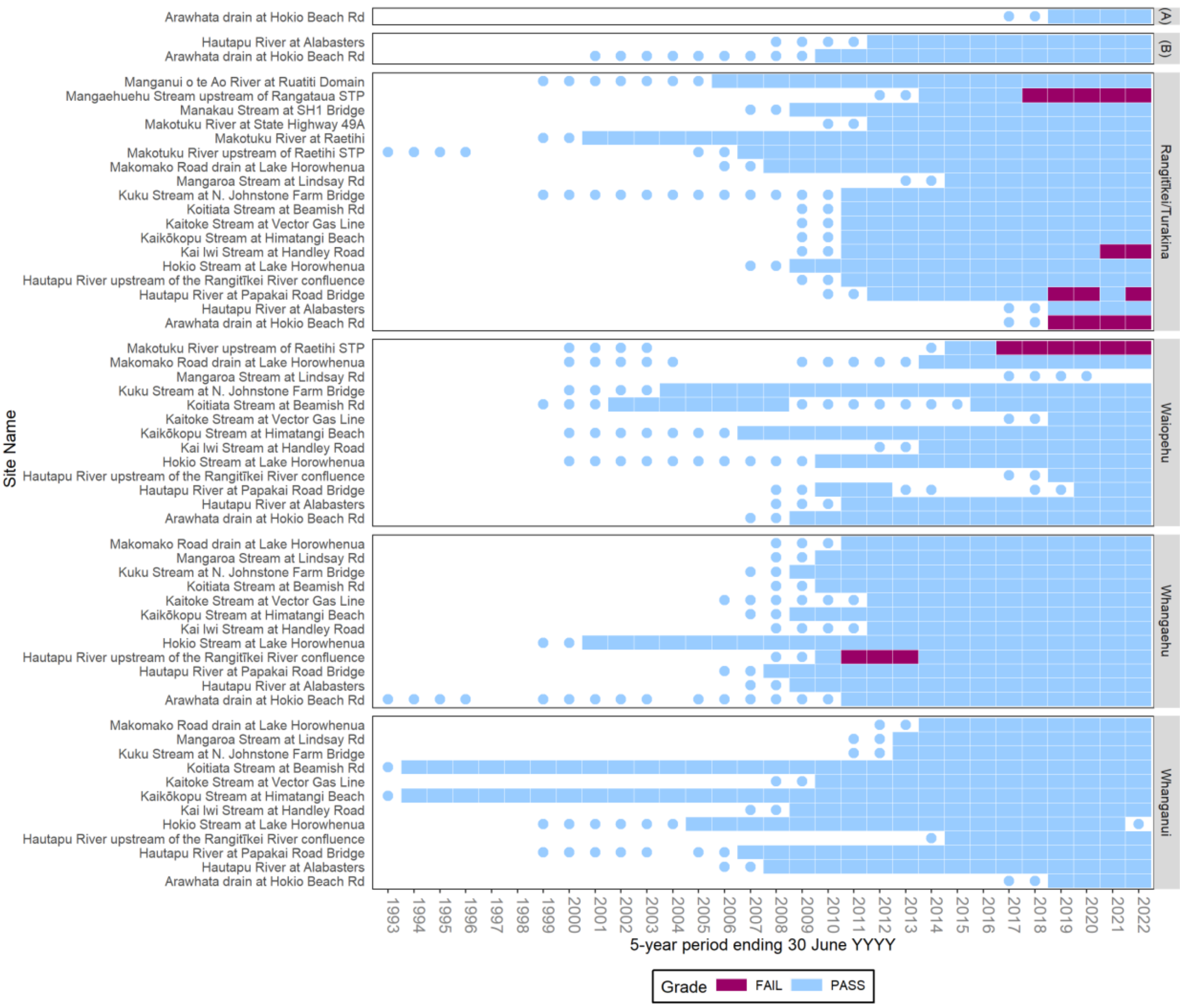

Figure 57: Rolling state assessment for One Plan river NH4-N (mean) target for sites outside of the Manawatu FMU. Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.10 Periphyton (filaments)

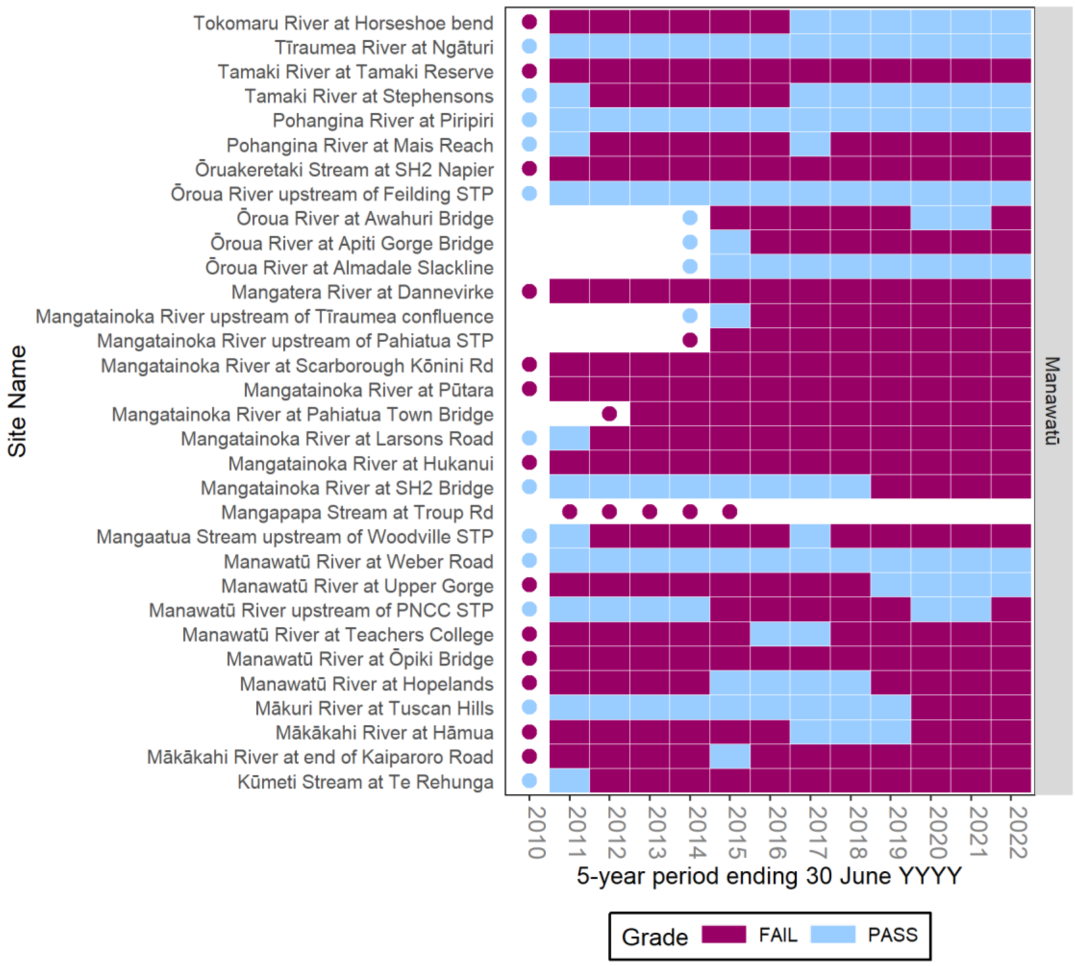

Figure 58: Rolling state assessment for One Plan river Periphyton (filaments) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

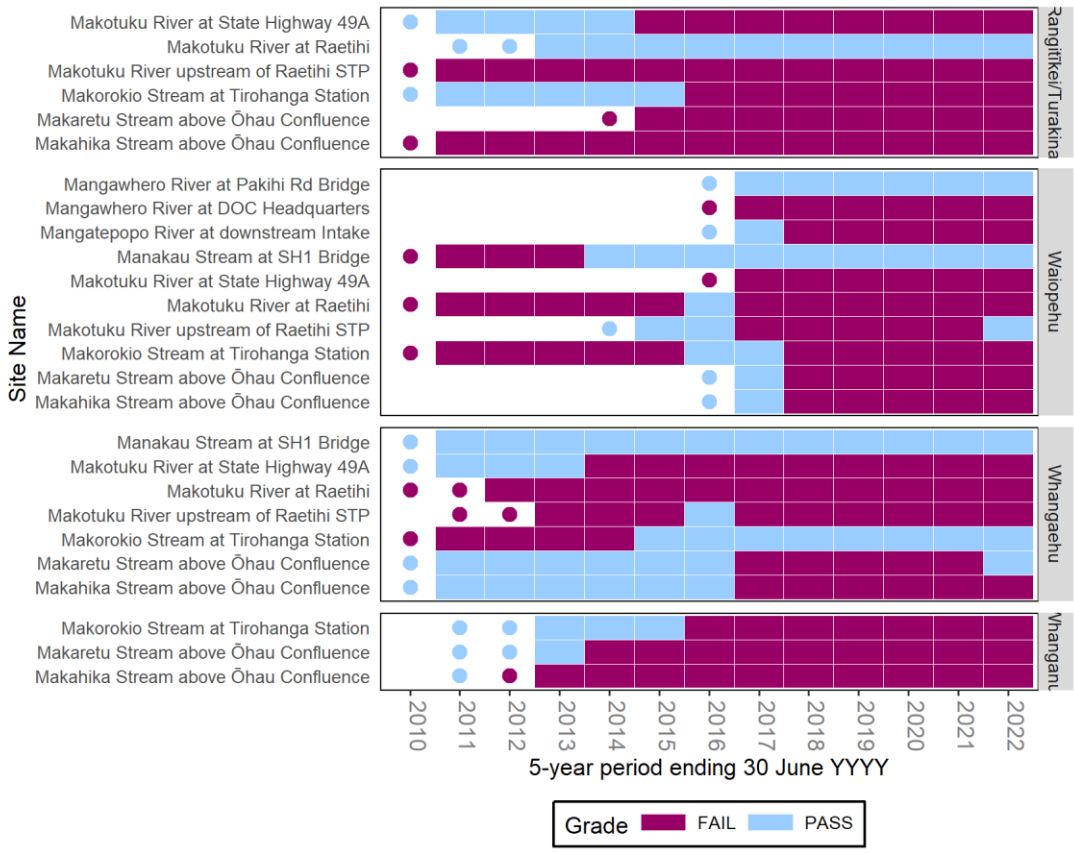

Figure 59: Rolling state assessment for One Plan river Periphyton (filaments) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.11 Periphyton (mats)

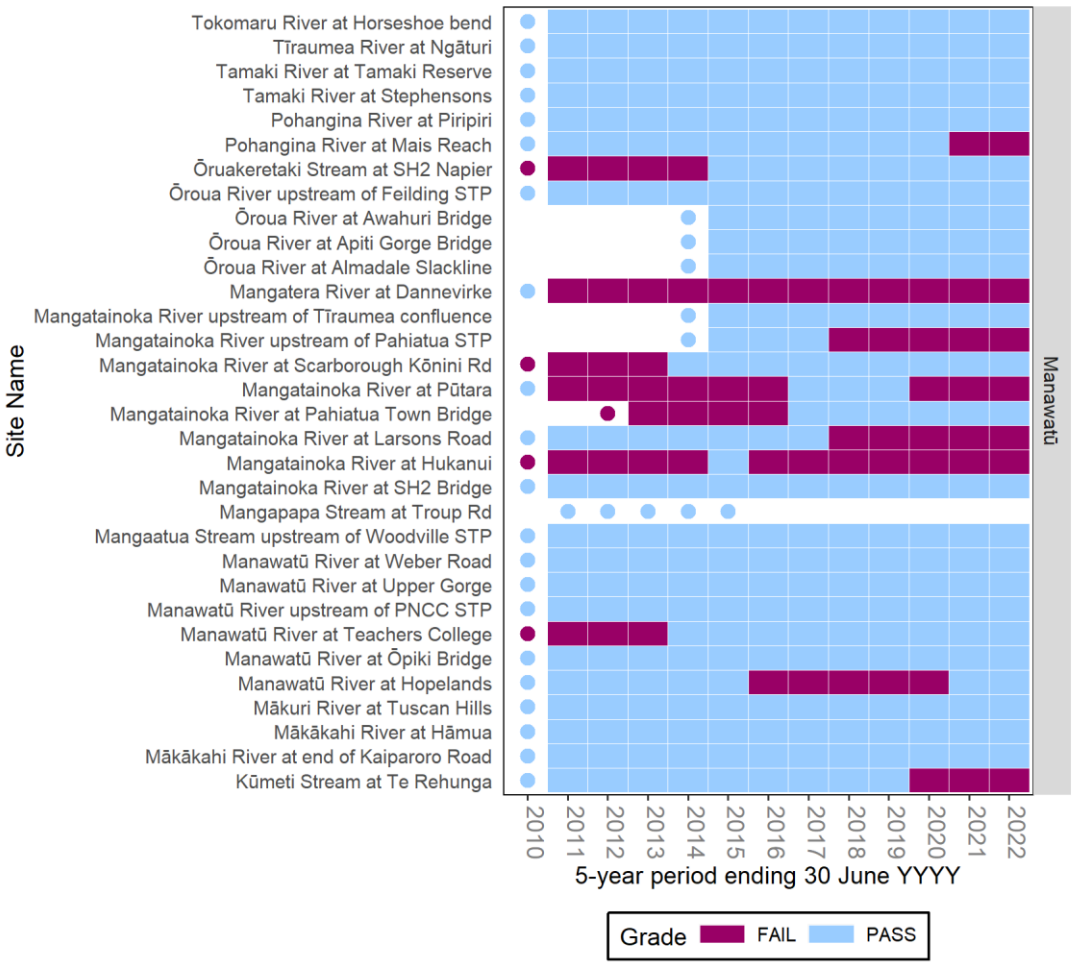

Figure 60: Rolling state assessment for One Plan river Periphyton (mats) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

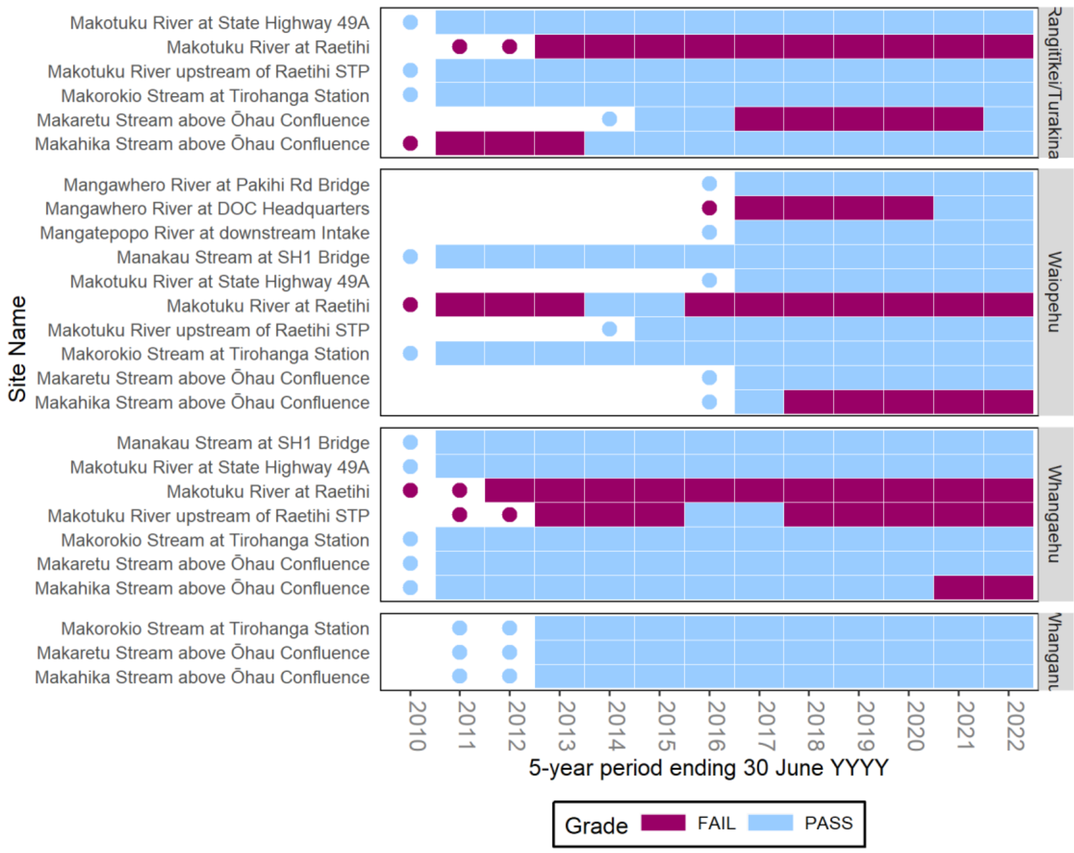

Figure 61: Rolling state assessment for One Plan river Periphyton (mats) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.12 POM

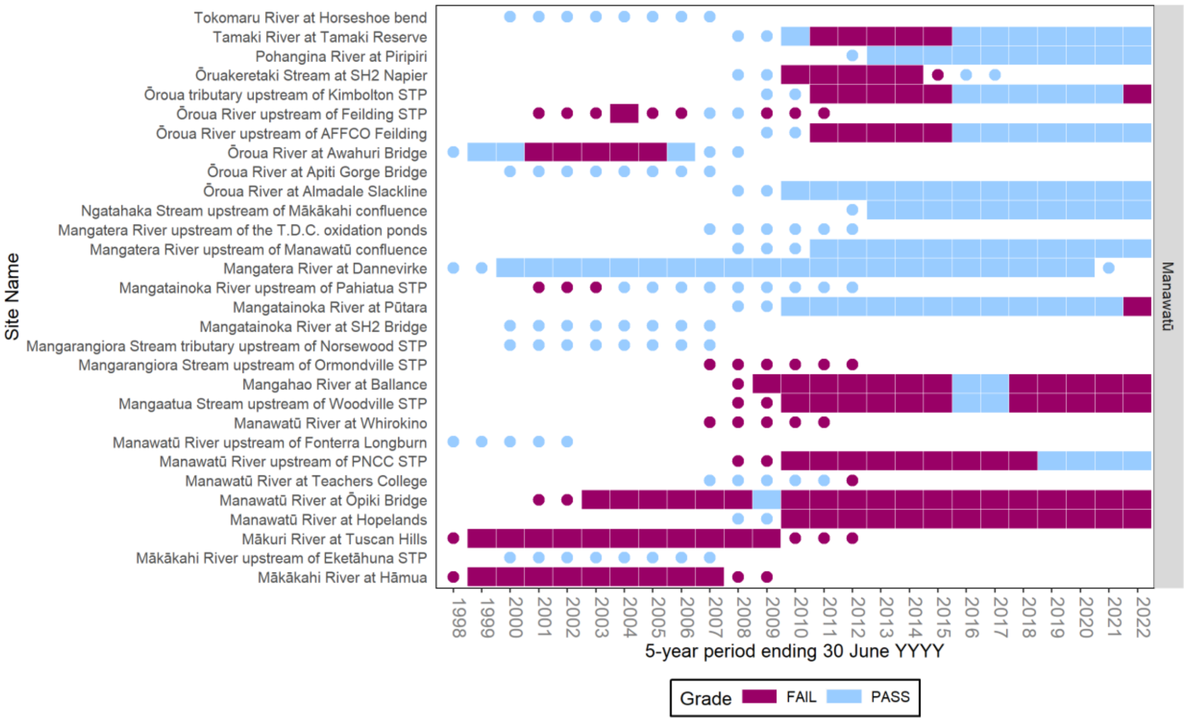

Figure 62: Rolling state assessment for One Plan river POM target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

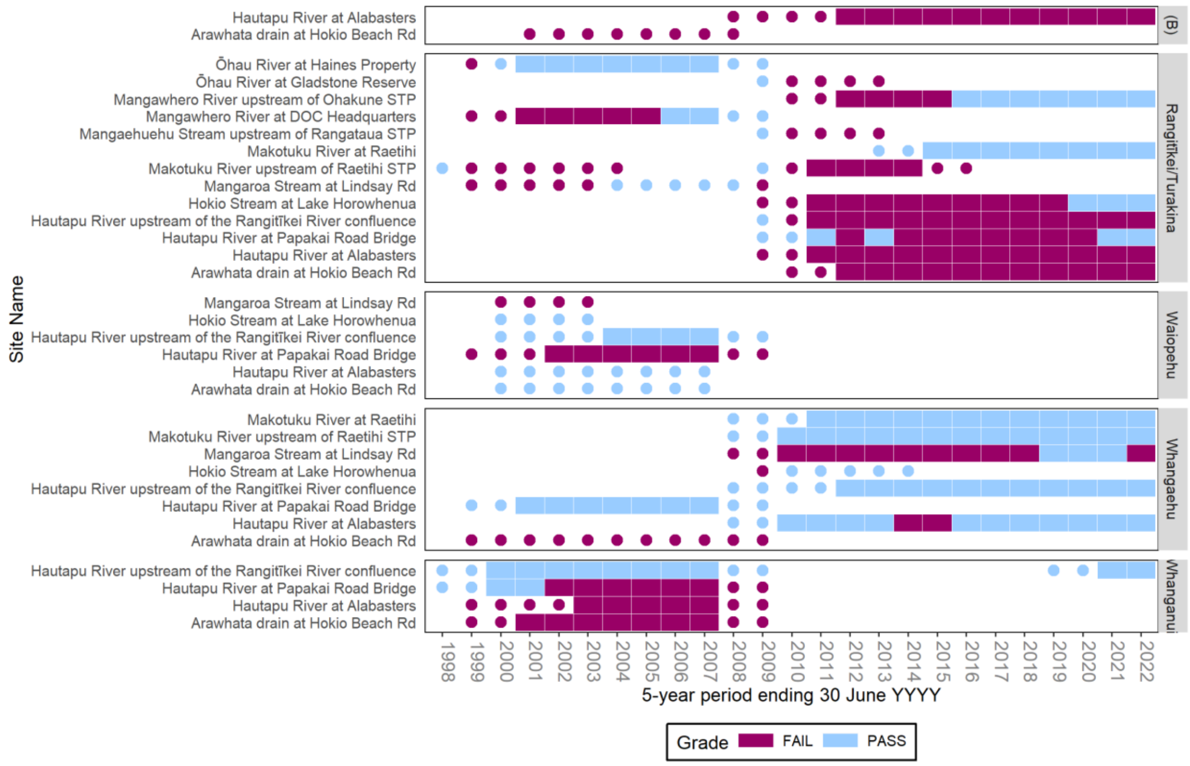

Figure 63: Rolling state assessment for One Plan river POM target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C1.13 sCBOB5

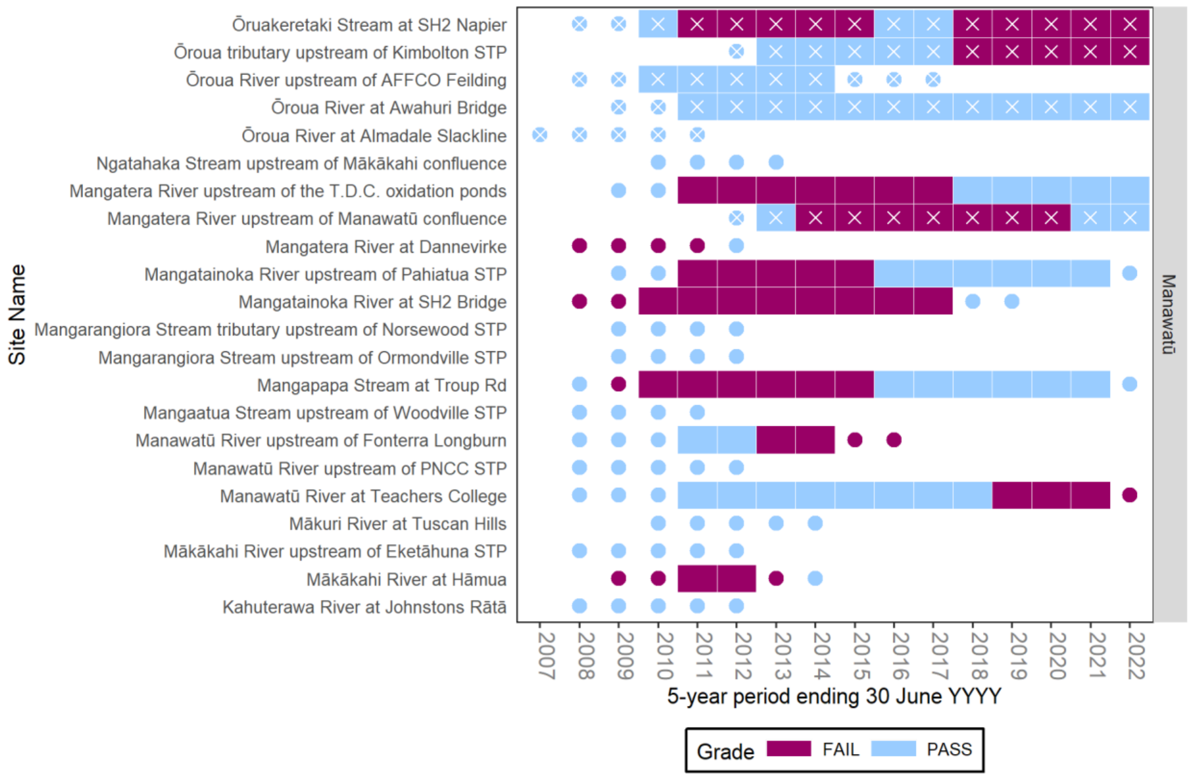

Figure 64: Rolling state assessment for One Plan river sCBOD5 target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

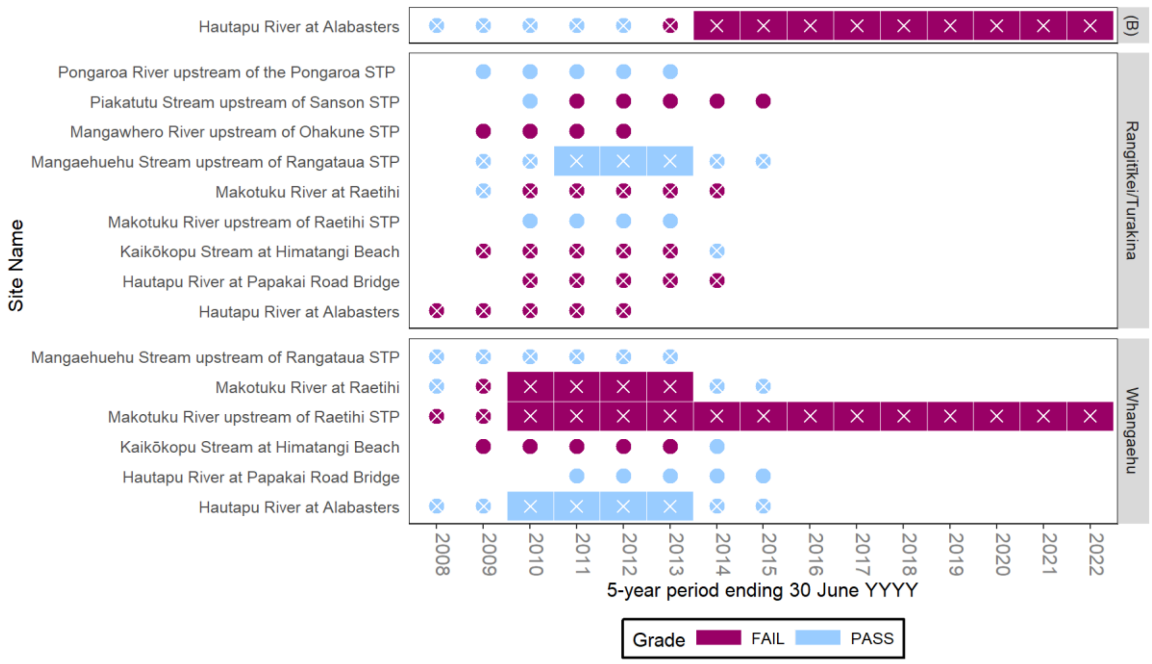

Figure 65: Rolling state assessment for One Plan river sCBOD5 target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C1.14 SIN

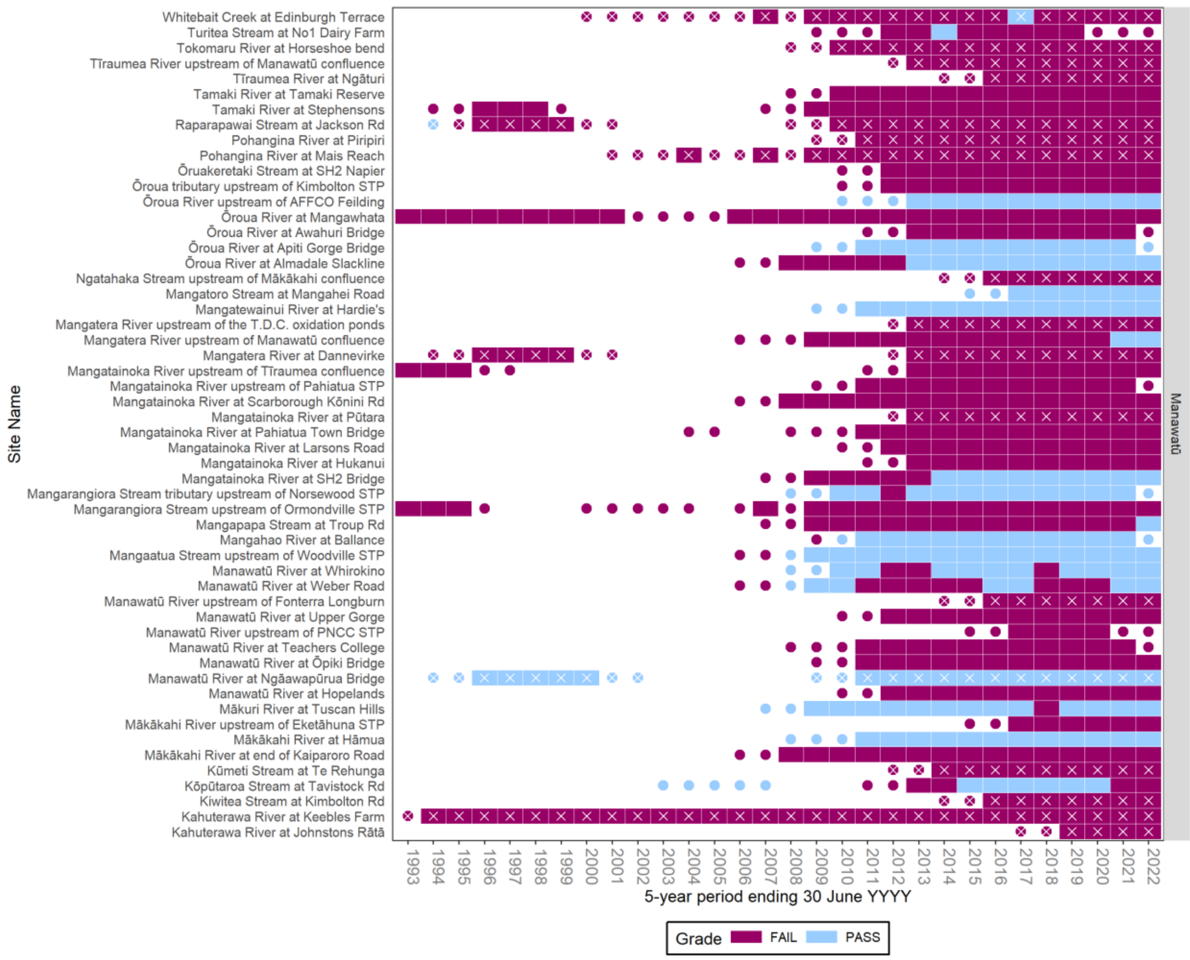

Figure 66: Rolling state assessment for One Plan river SIN target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

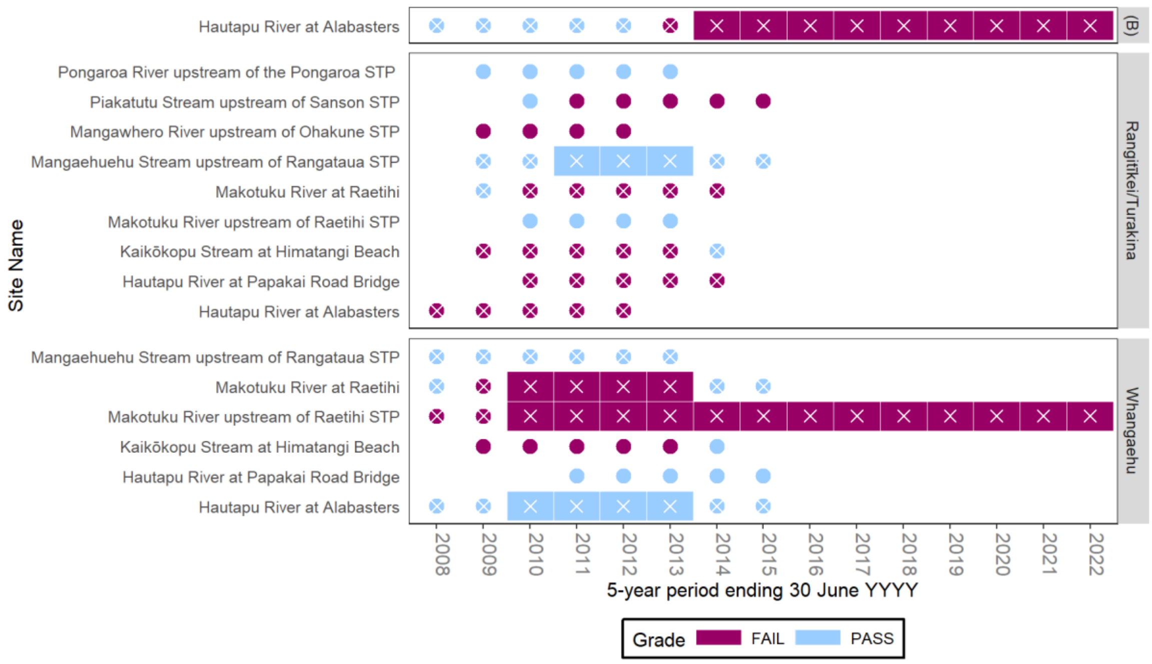

Figure 67: Rolling state assessment for One Plan river SIN target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2 River impact sites

C2.1 Chloropyll-a

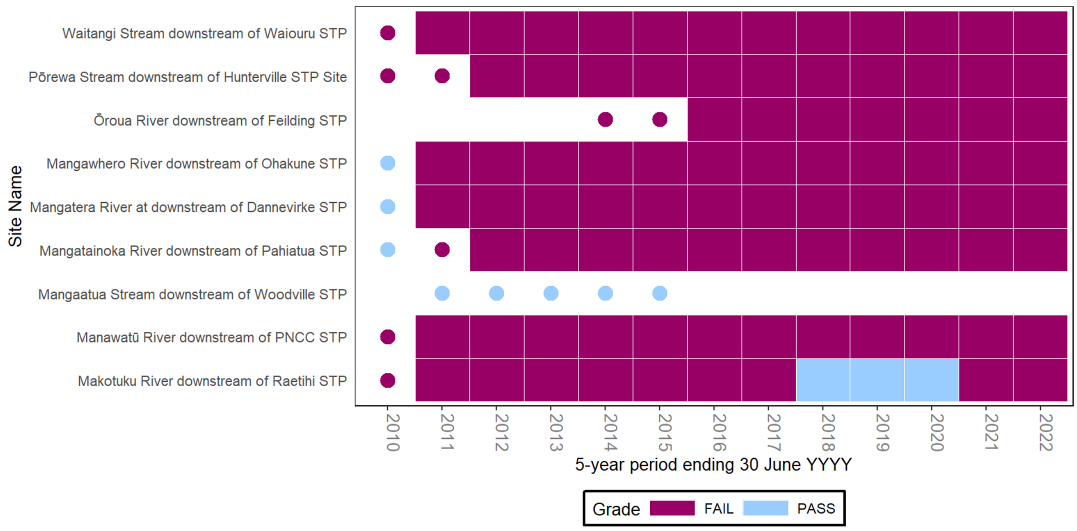

Figure 68: Rolling state assessment for One Plan river chlorophyll-a target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours

indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.2 Clarity

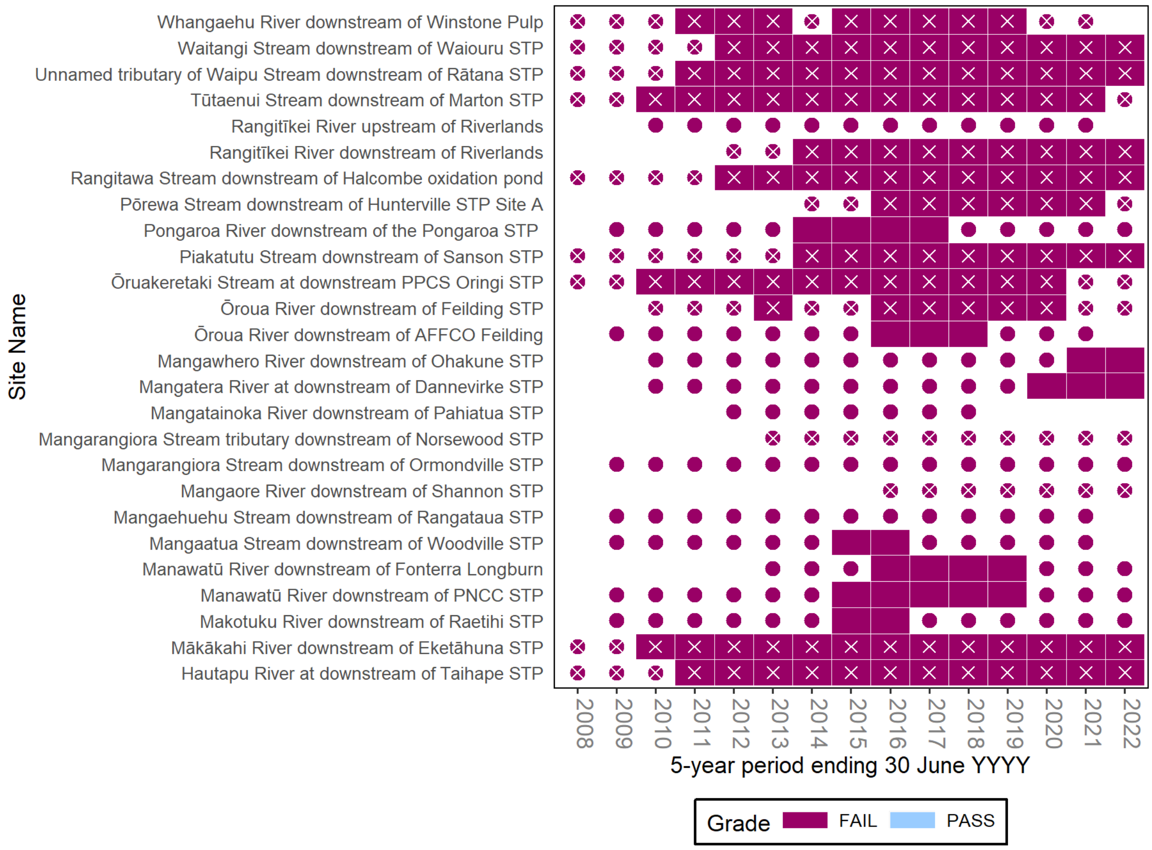

Figure 69: Rolling state assessment for One Plan river clarity target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2.3 DO (Sat)

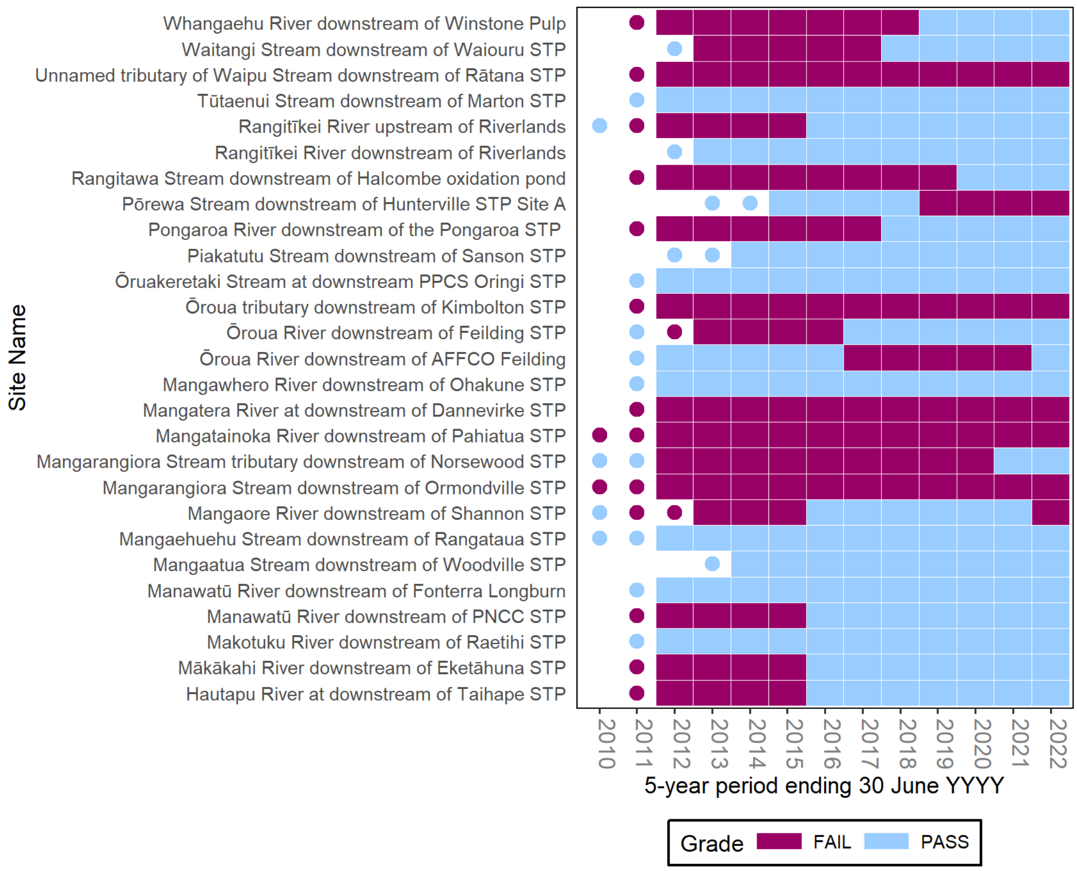

Figure 70: Rolling state assessment for One Plan river DO (sat) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.4 DRP

Figure 71: Rolling state assessment for One Plan river DRP target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2.5 E. coli (bathing)

Figure 72: Rolling state assessment for One Plan river E. coli (bathing) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2.6 E. coli (year round)

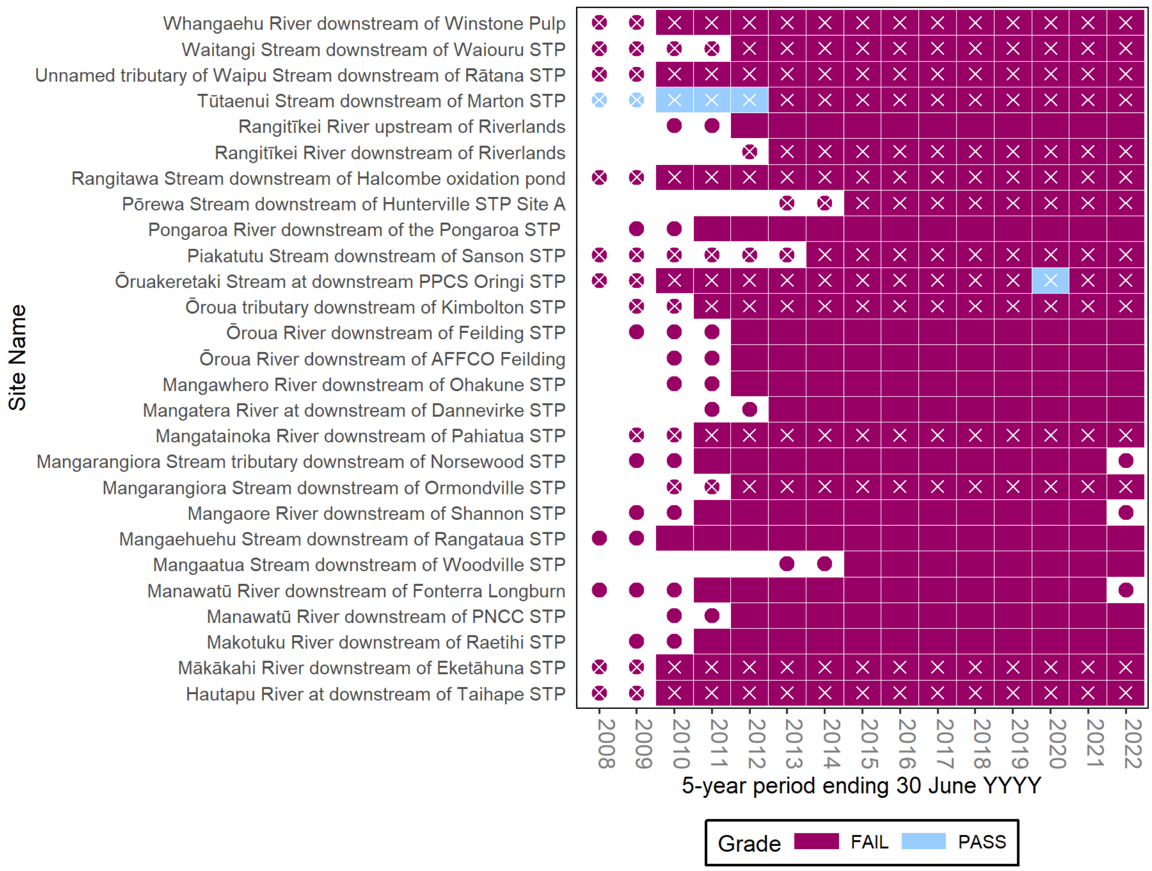

Figure 73: Rolling state assessment for One Plan river E. coli (year round) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2.7 MCI

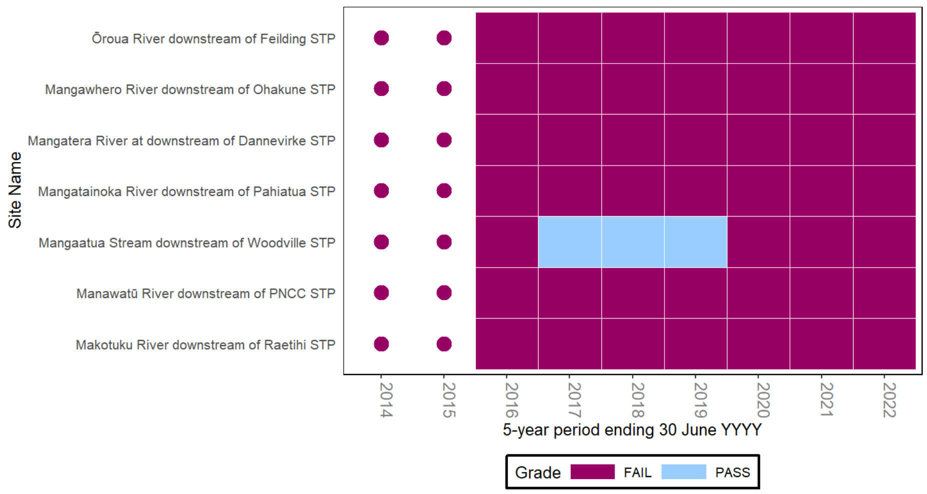

Figure 74: Rolling state assessment for One Plan river MCI target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.8 NH4-N (max)

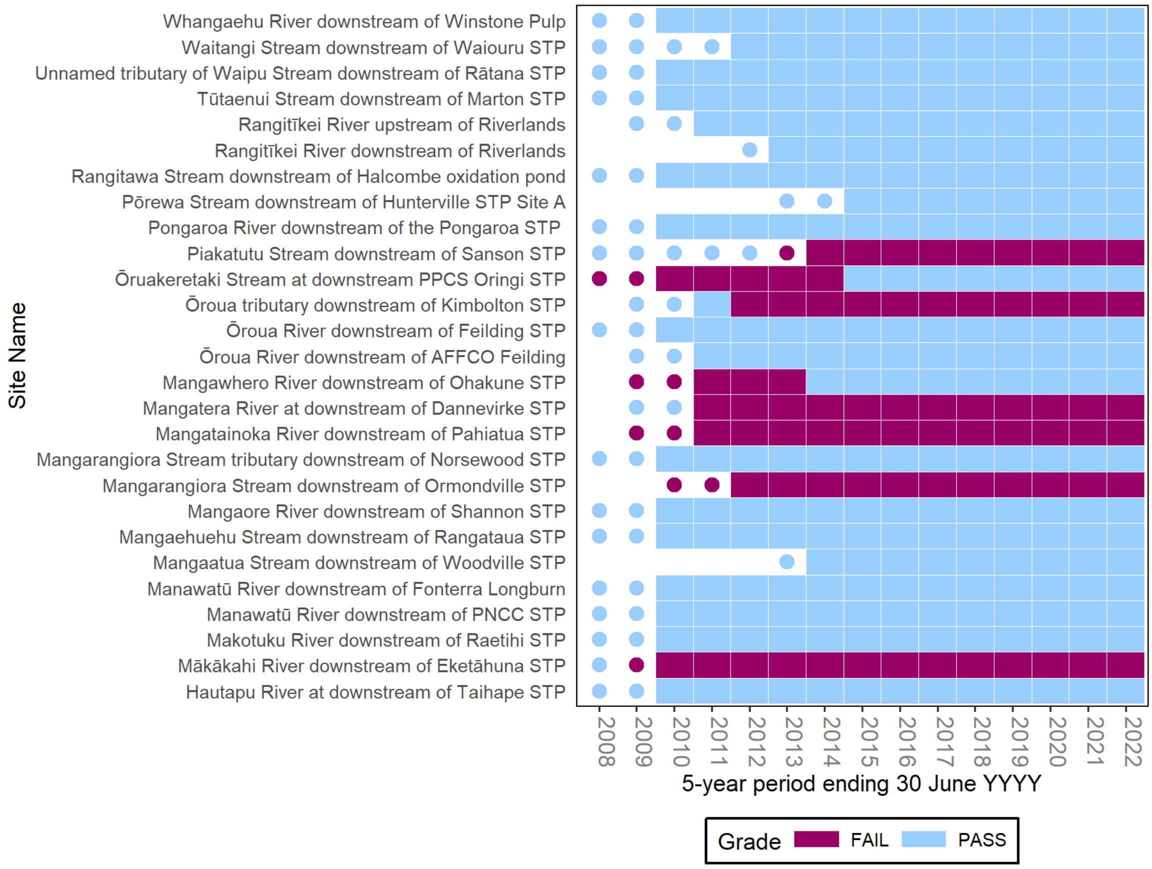

Figure 75: Rolling state assessment for One Plan river NH4N (max) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.9 NH4-N (mean)

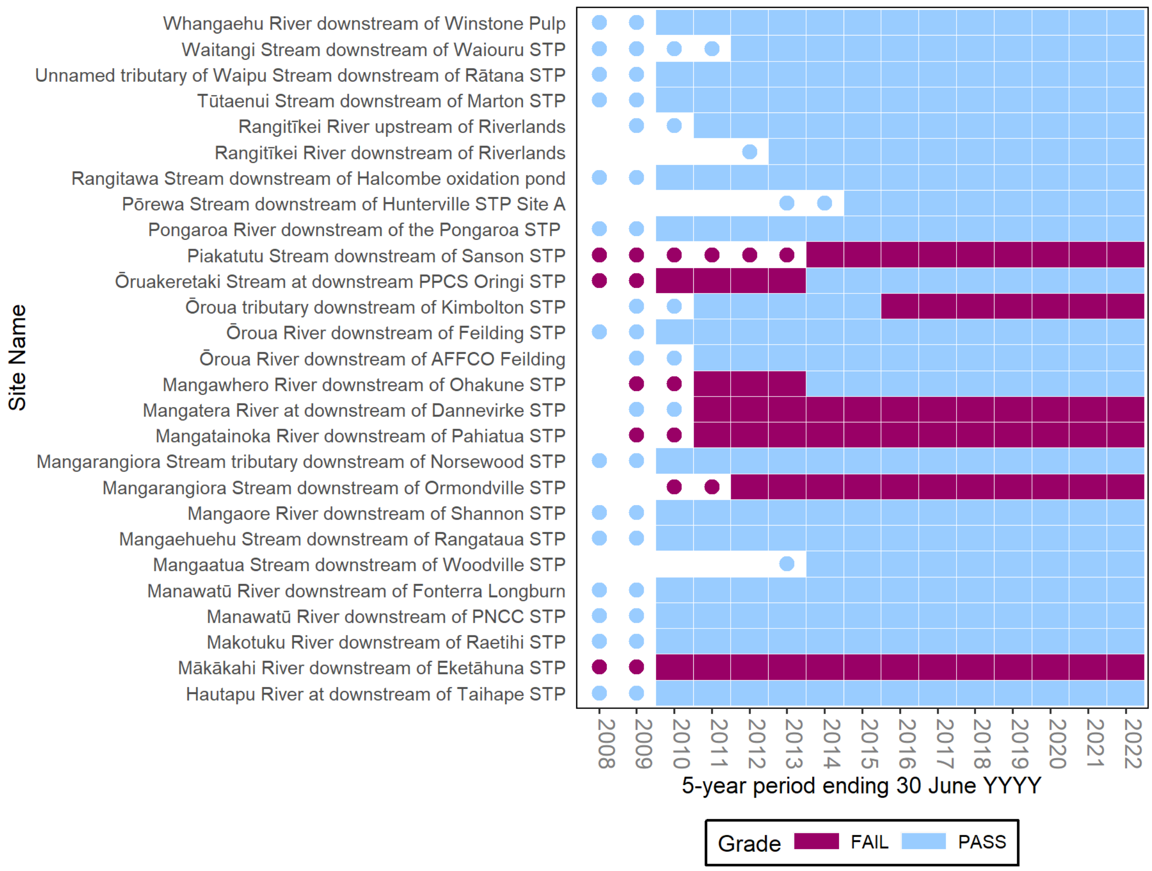

Figure 76: Rolling state assessment for One Plan river NH4N (mean) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.10 Periphyton (filaments)

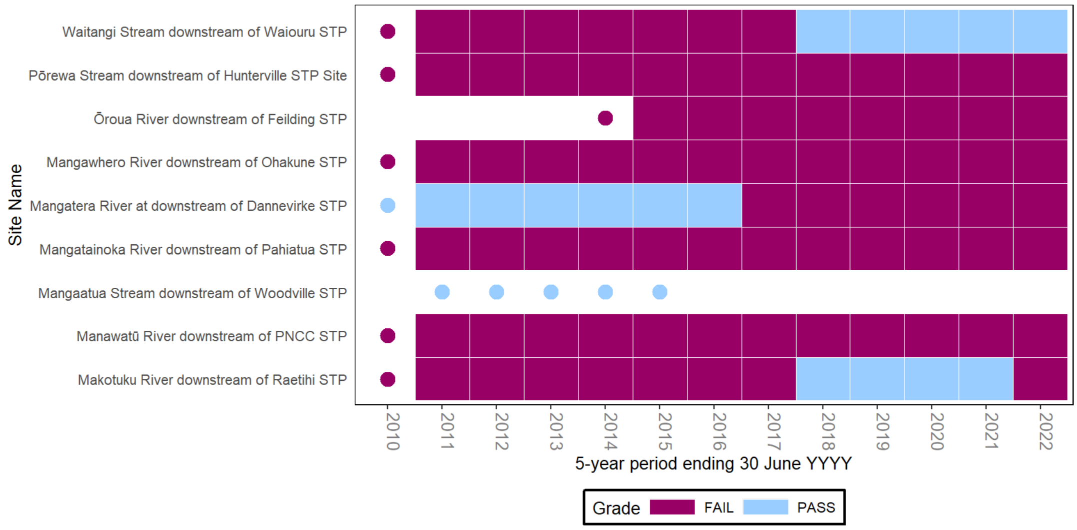

Figure 77: Rolling state assessment for One Plan river Periphyton (filaments) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.11 Periphyton (mats)

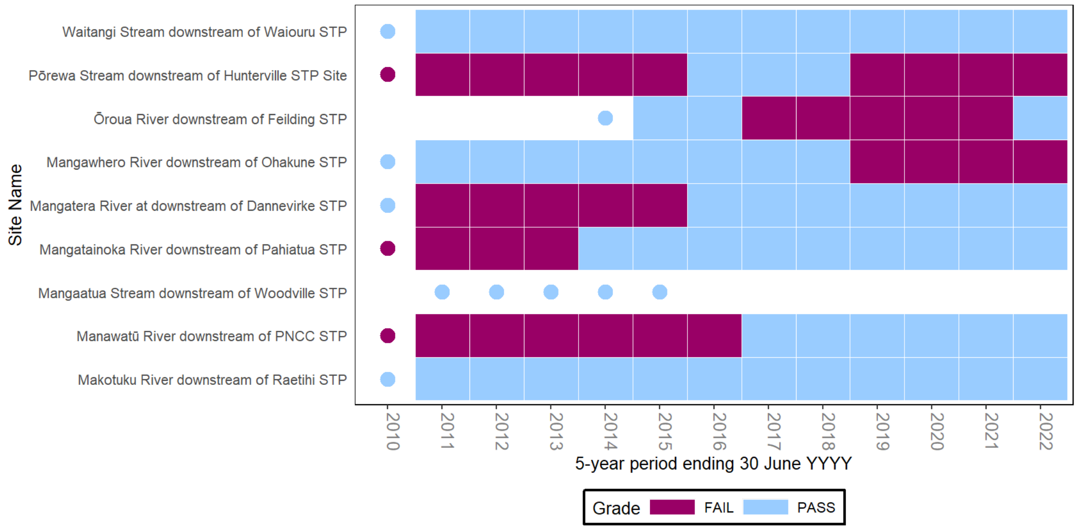

Figure 78: Rolling state assessment for One Plan river Periphyton (mats) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.12 POM

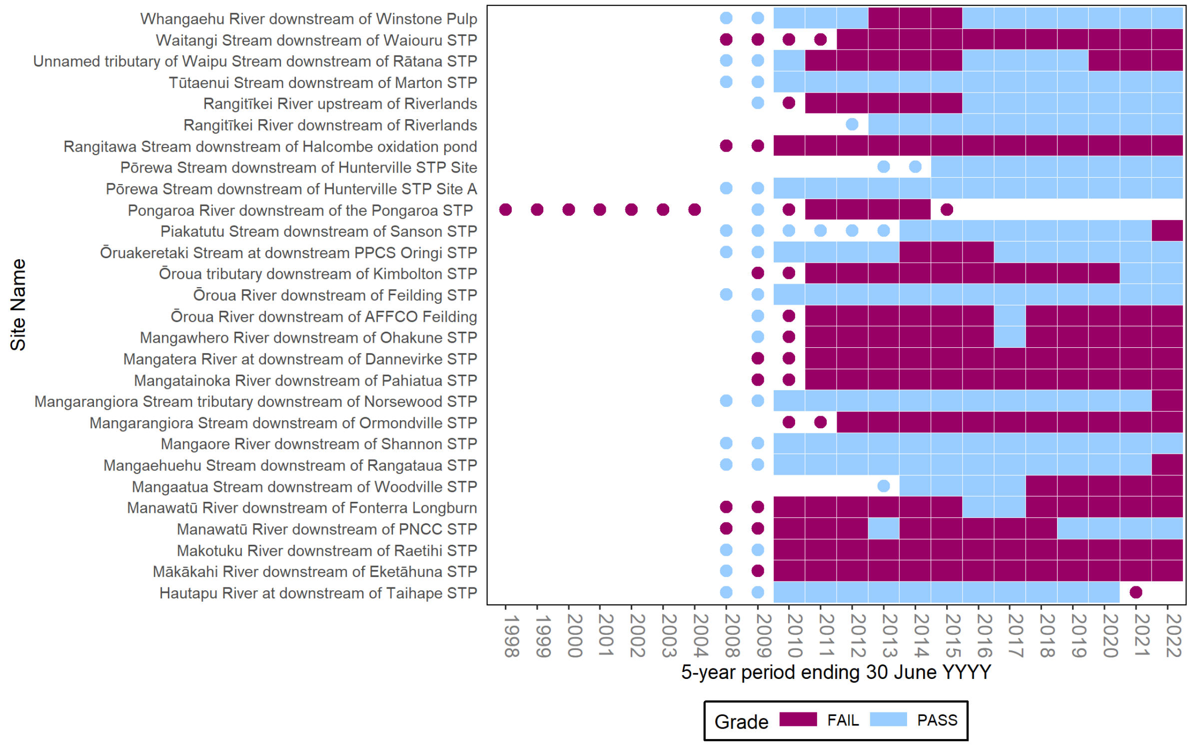

Figure 79: Rolling state assessment for One Plan river POM target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C2.13 sCBOB5

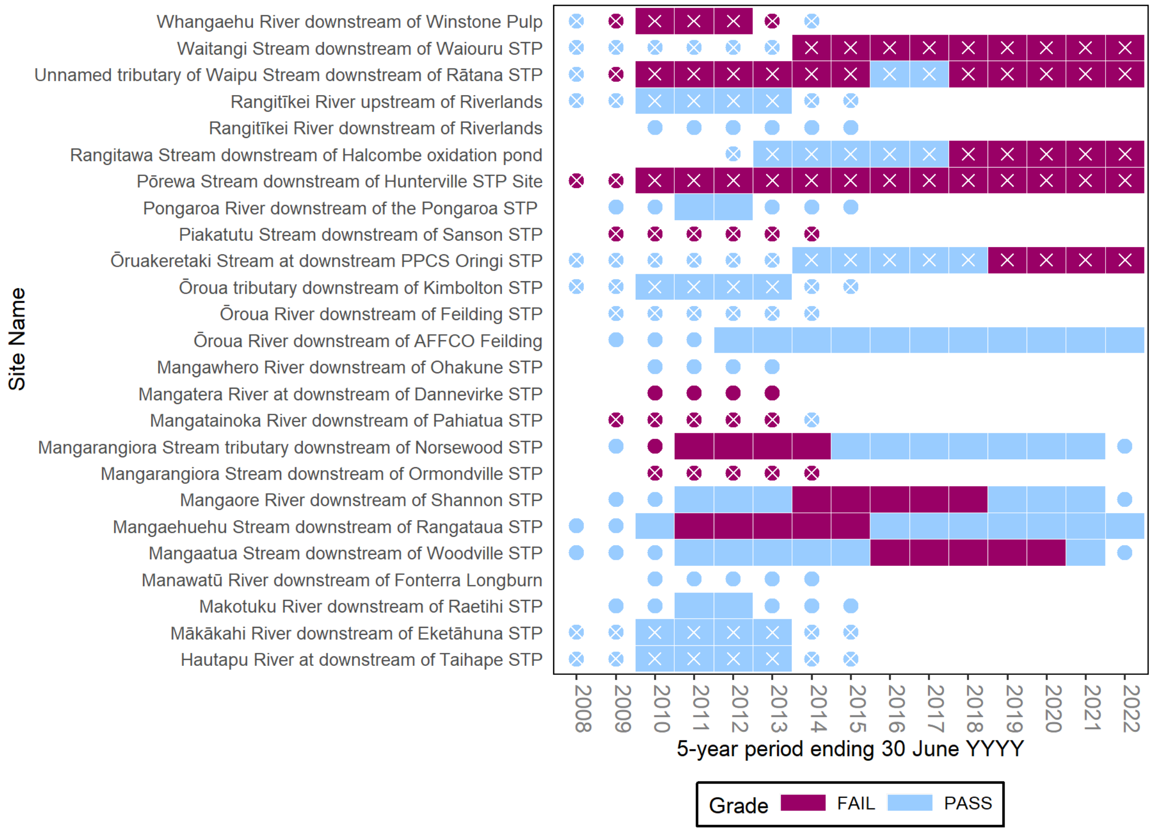

Figure 80: Rolling state assessment for One Plan river sCBOD5 target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2.14 SIN

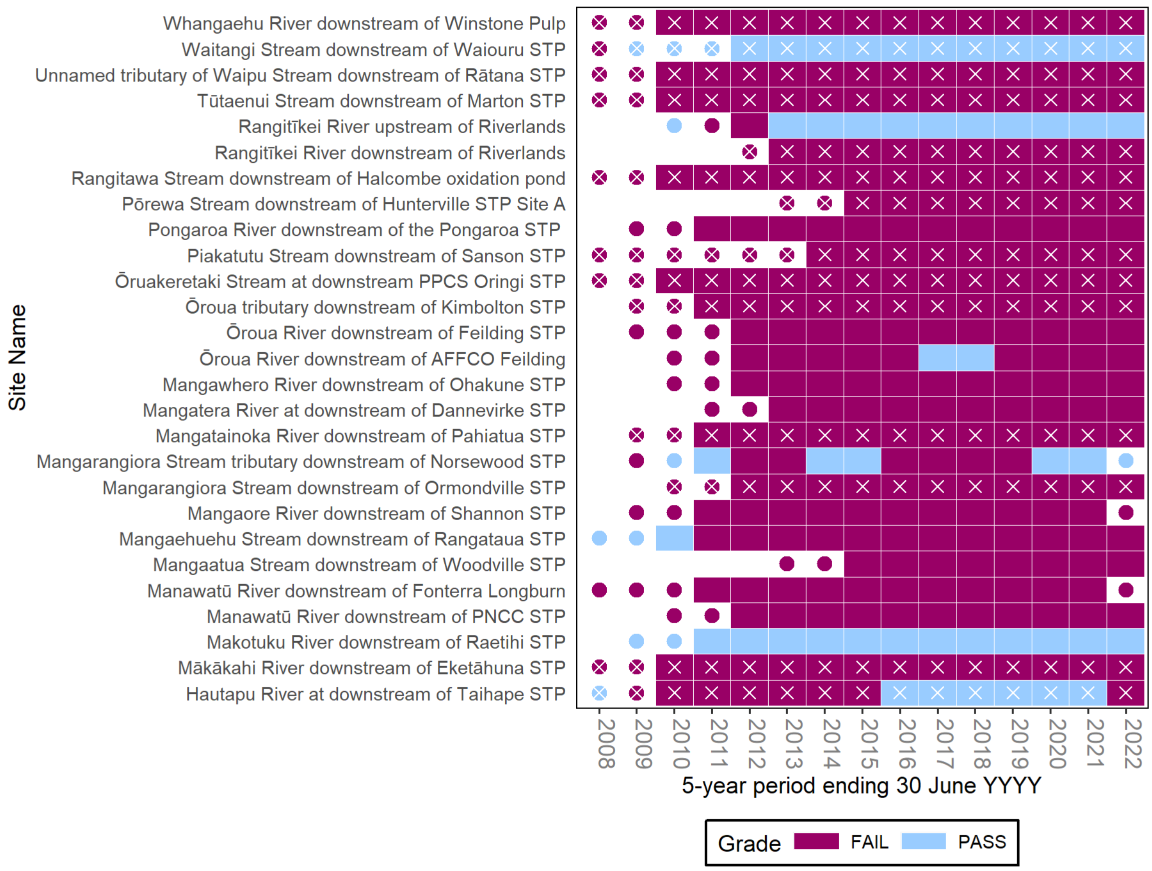

Figure 81: Rolling state assessment for One Plan river SIN target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C3 River discharge sites

C3.1 pH (change)

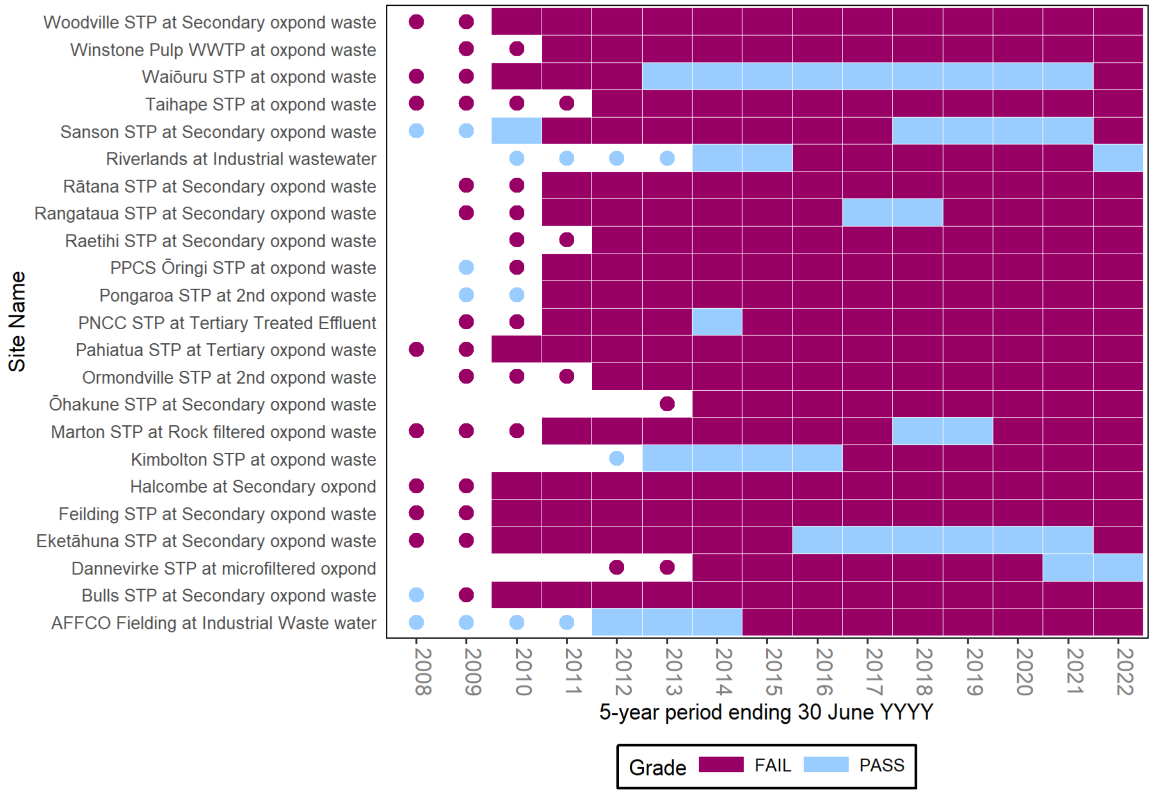

Figure 82: Rolling state assessment for One Plan river pH (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C3.2 Temperature (change)

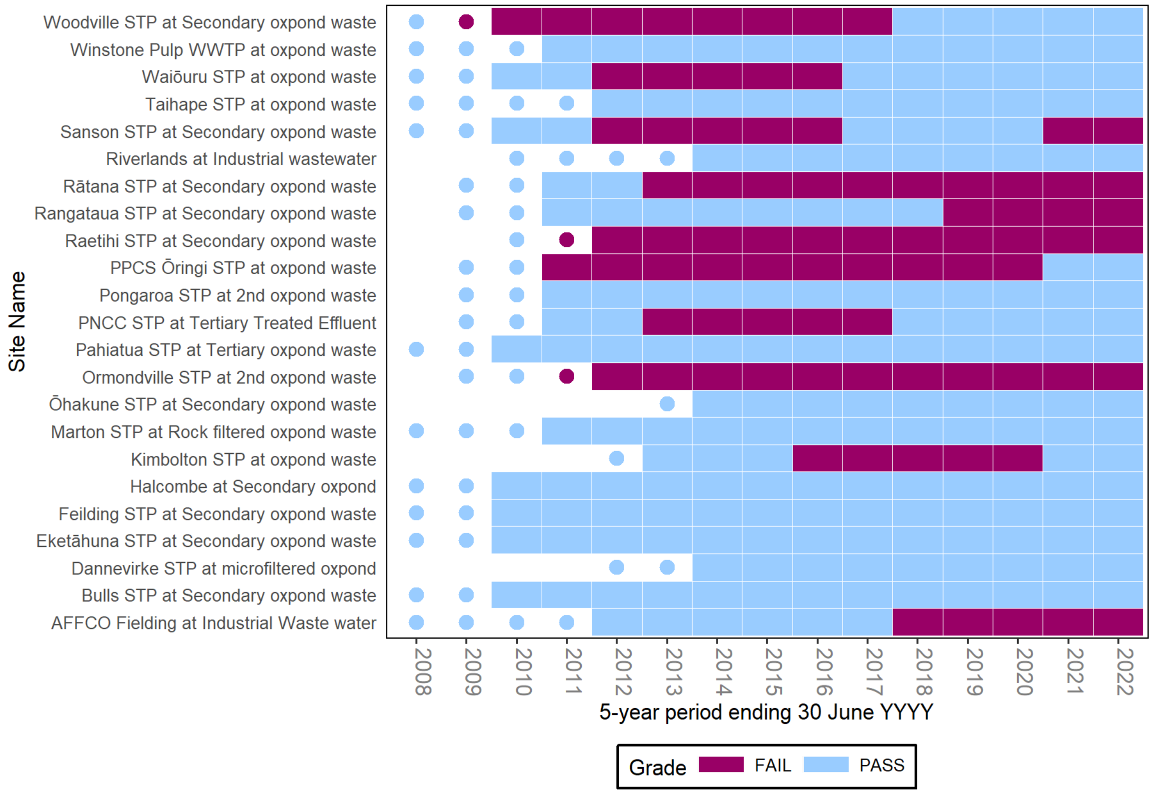

Figure 83: Rolling state assessment for One Plan river temperature (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C3.3 Clarity (change)

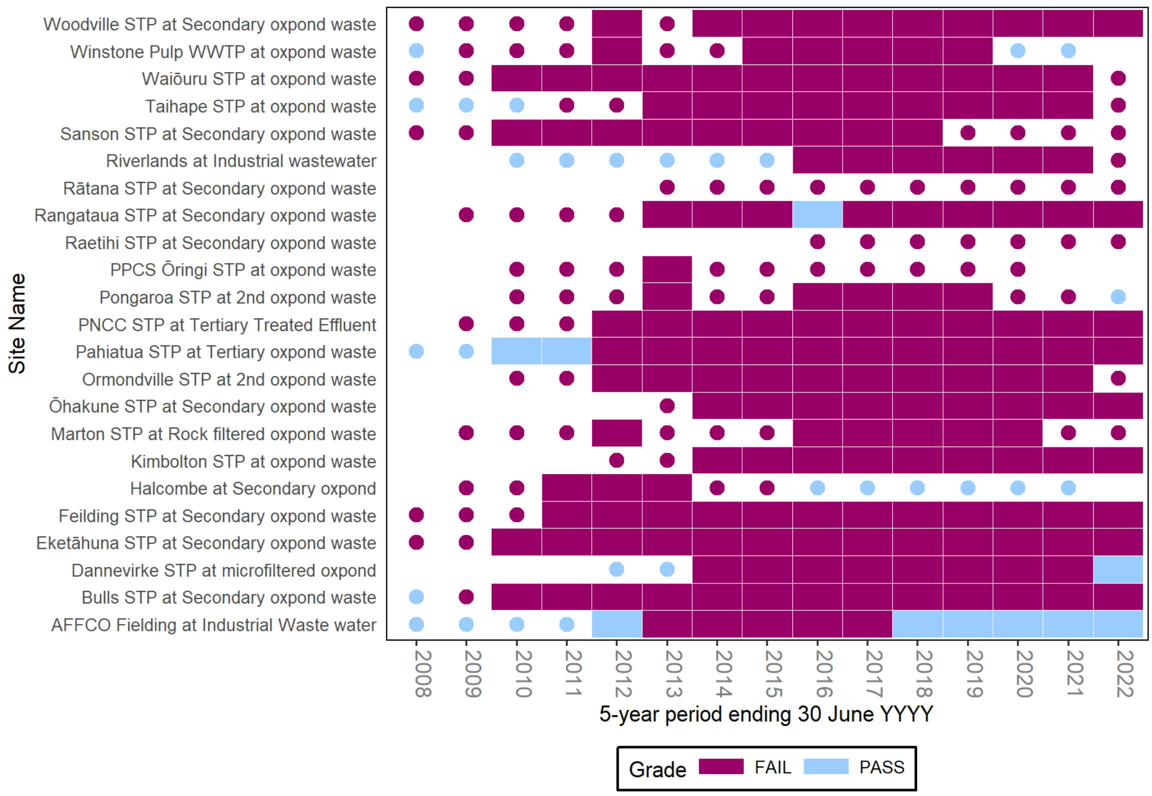

Figure 84: Rolling state assessment for One Plan river clarity (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C3.4 QMCI (change)

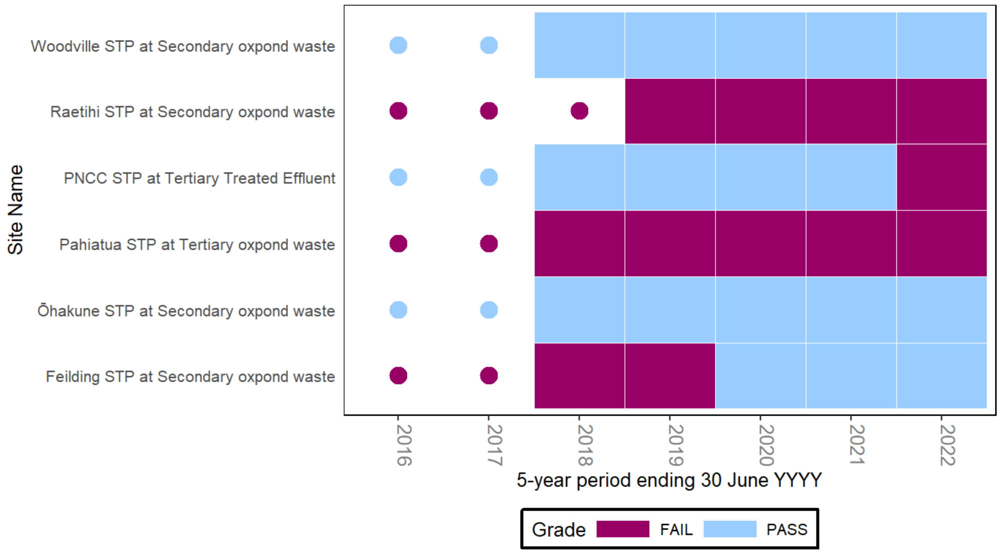

Figure 85: Rolling state assessment for One Plan river QMCI (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4 Lakes

C4.1 Chlorophyll-a (mean)

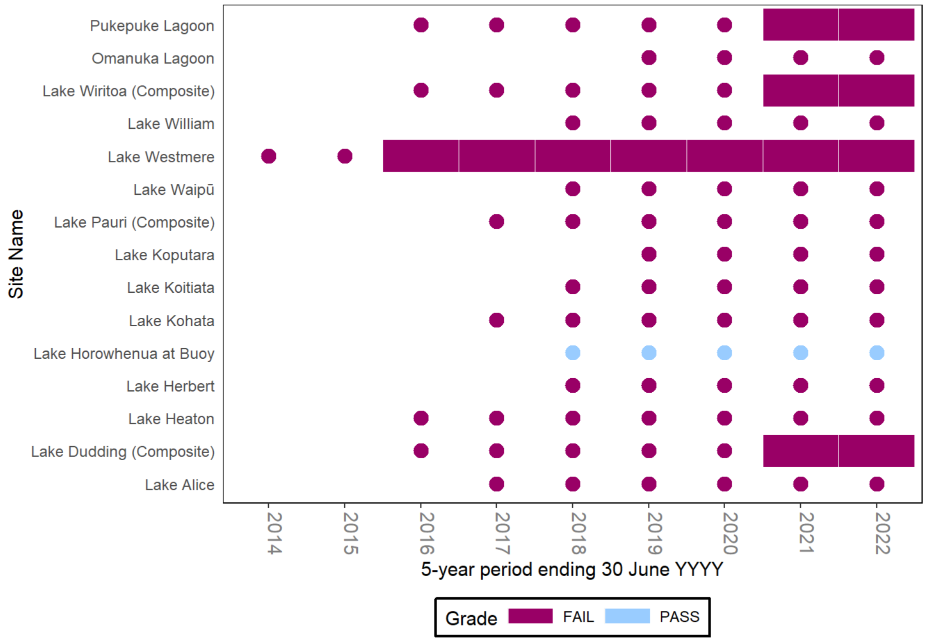

Figure 86: Rolling state assessment for One Plan chlorophyll-a (mean) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4.2 Chlorophyll-a (max)

Figure 87: Rolling state assessment for One Plan chlorophyll-a (meax) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4.3 Clarity

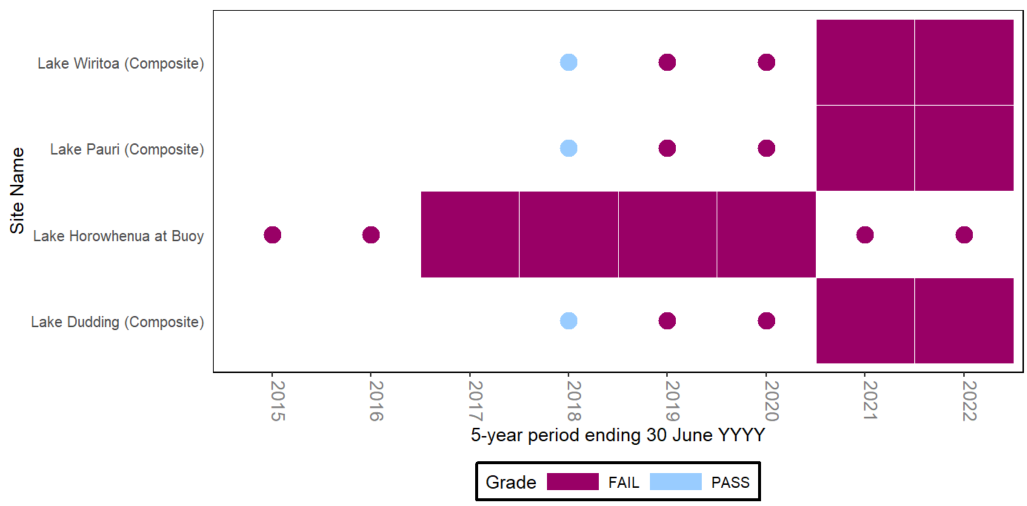

Figure 88: Rolling state assessment for One Plan clarity target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4.4 E. coli (bathing)

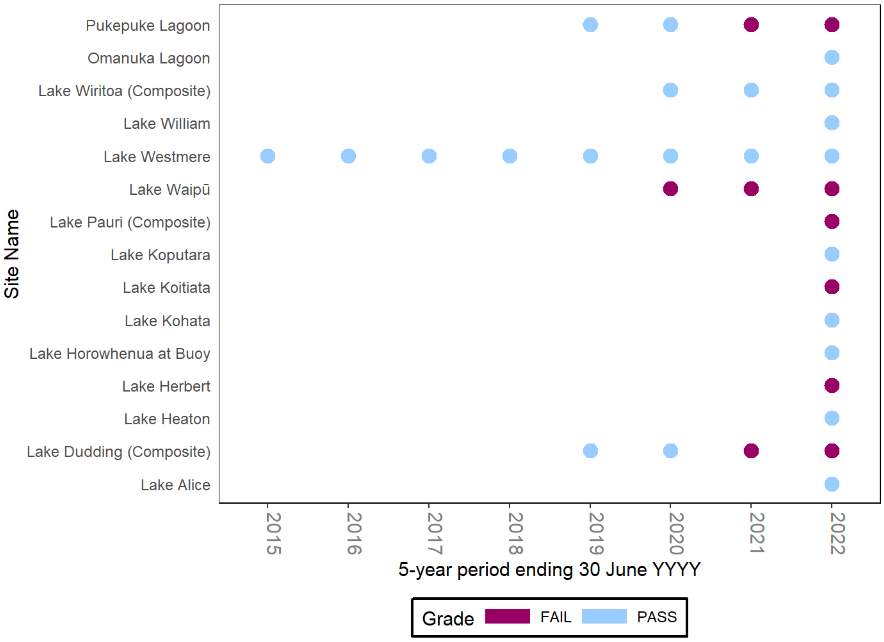

Figure 89: Rolling state assessment for One Plan E. coli (bathing) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4.5 E. coli (non-bathing)

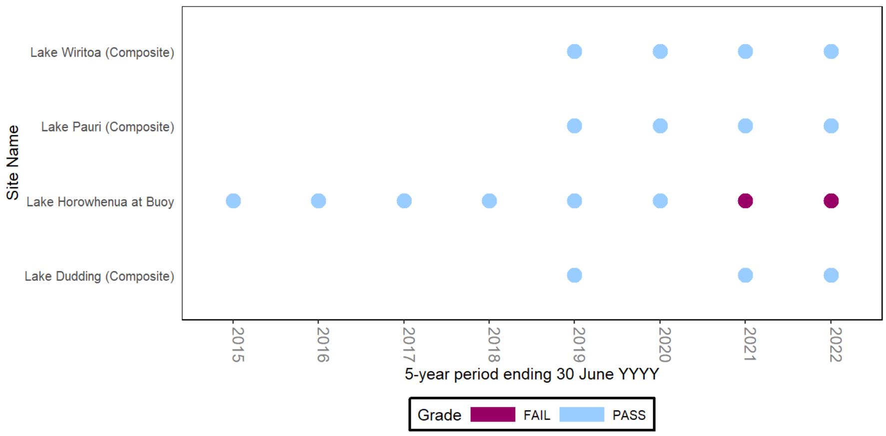

Figure 90: Rolling state assessment for One Plan E. coli (non-bathing) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4.6 TN

Figure 91: Rolling state assessment for One Plan TN target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C4.7 TP

Figure 92: Rolling state assessment for One Plan TP target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C5 Estuary

C5.1 Chlorophyll-a

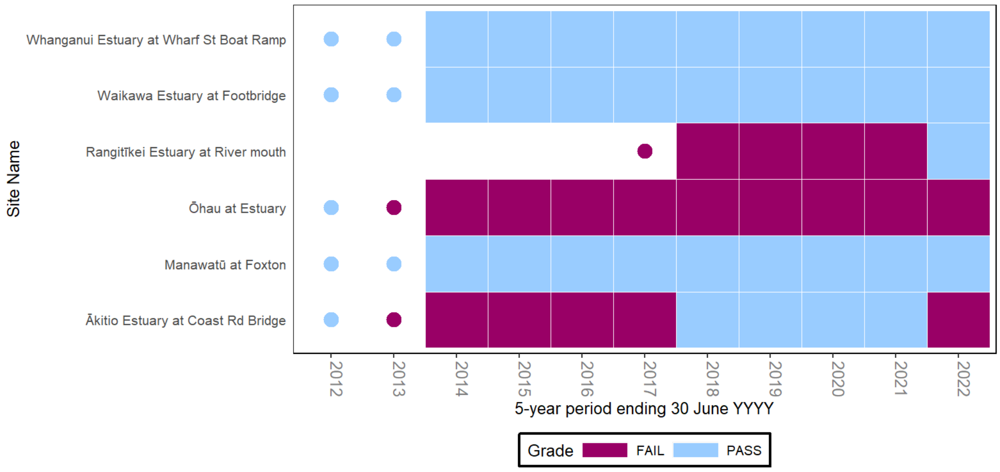

Figure 93: Rolling state assessment for One Plan chlorophyll-a target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C5.2 Clarity

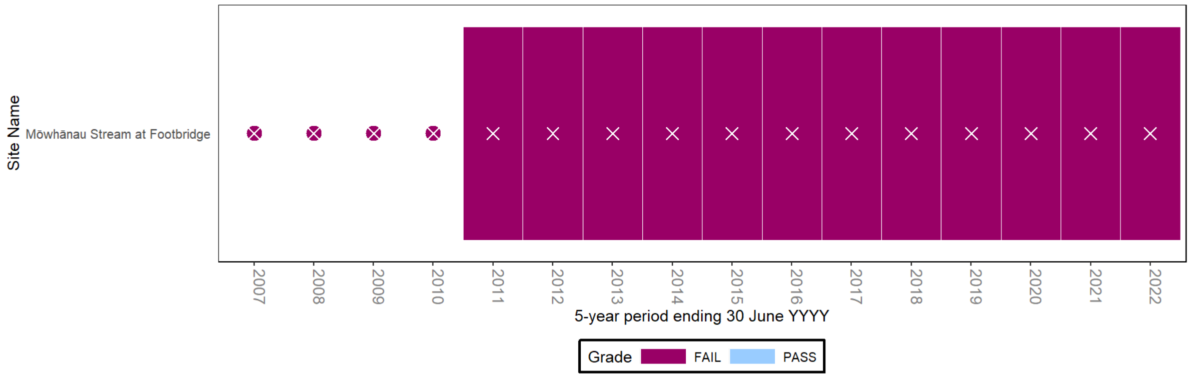

Figure 94: Rolling state assessment for One Plan clarity target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C5.3 DO (Sat)

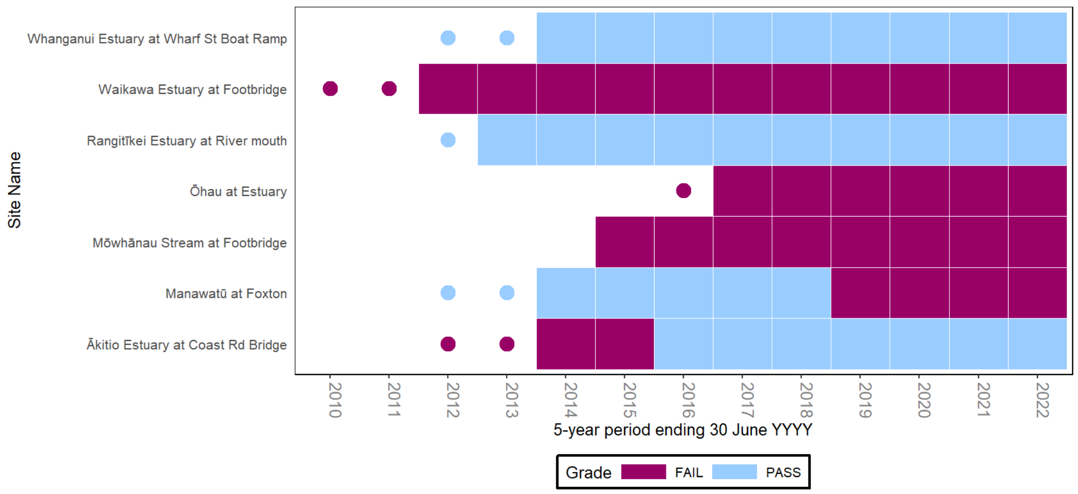

Figure 95: Rolling state assessment for One Plan DO (Sat) target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C5.4 DRP

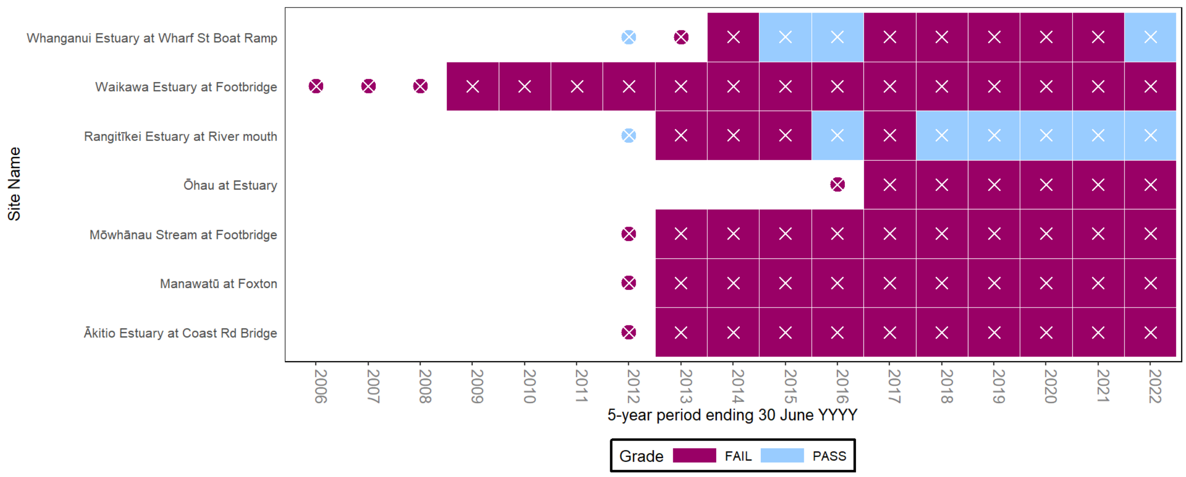

Figure 96: Rolling state assessment for One Plan DRP target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C5.5 E. coli (bathing)

Figure 97: Rolling state assessment for One Plan E. coli (bathing) target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C5.6 E. coli (year round)

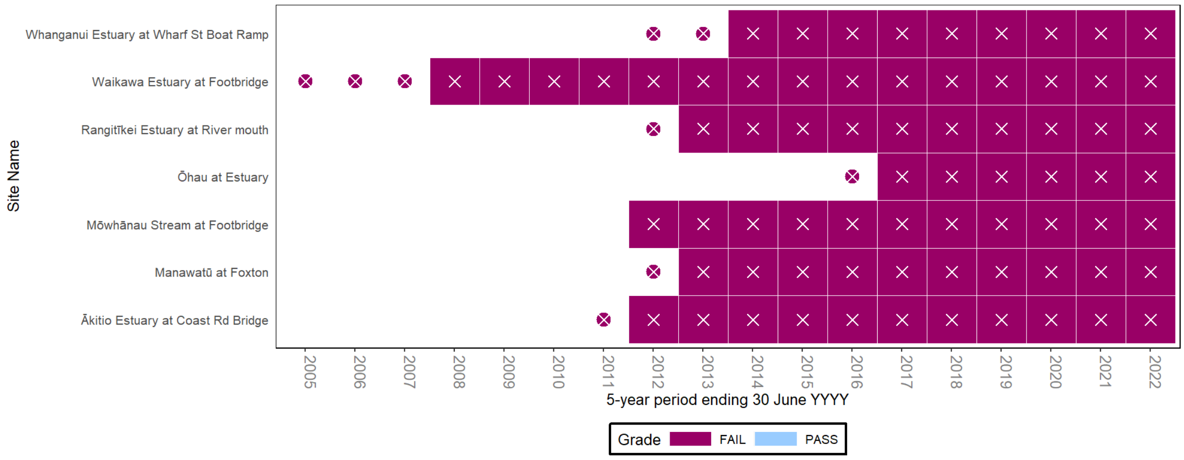

Figure 98: Rolling state assessment for One Plan E. coli (year round) target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C5.7 NH4-N

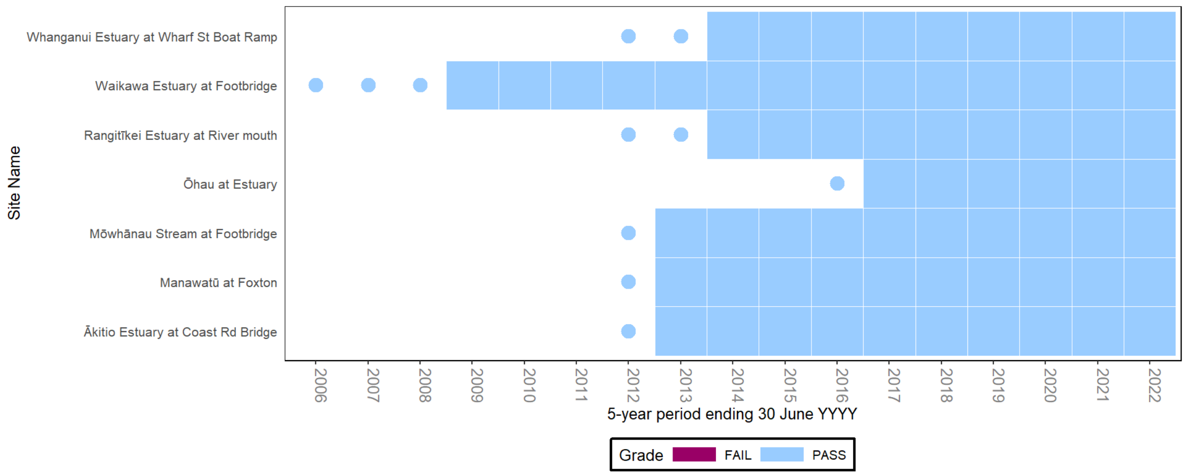

Figure 99: Rolling state assessment for One Plan NH4-N target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C5.8 SIN

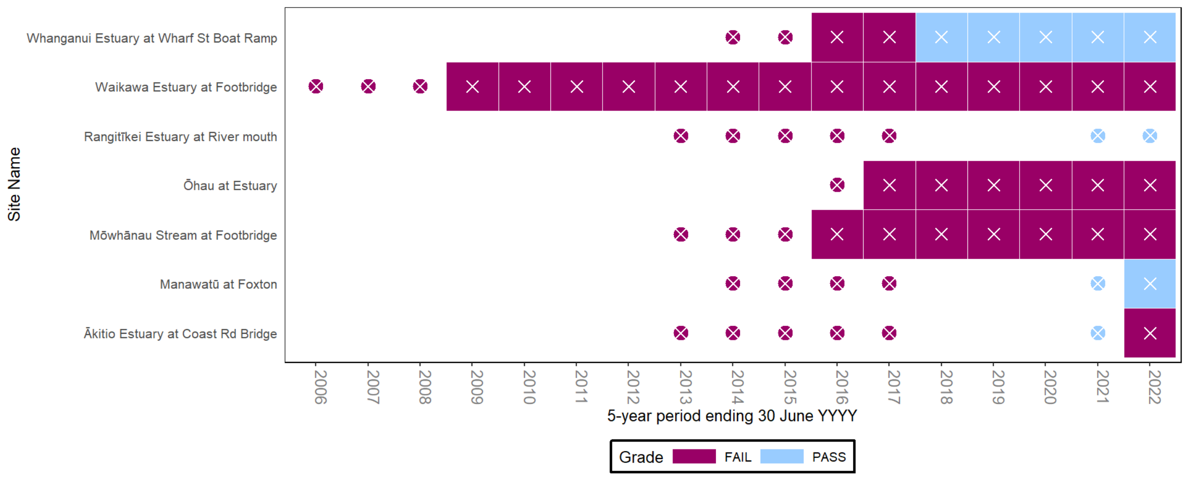

Figure 100: Rolling state assessment for One Plan SIN target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C5.9 Temperature

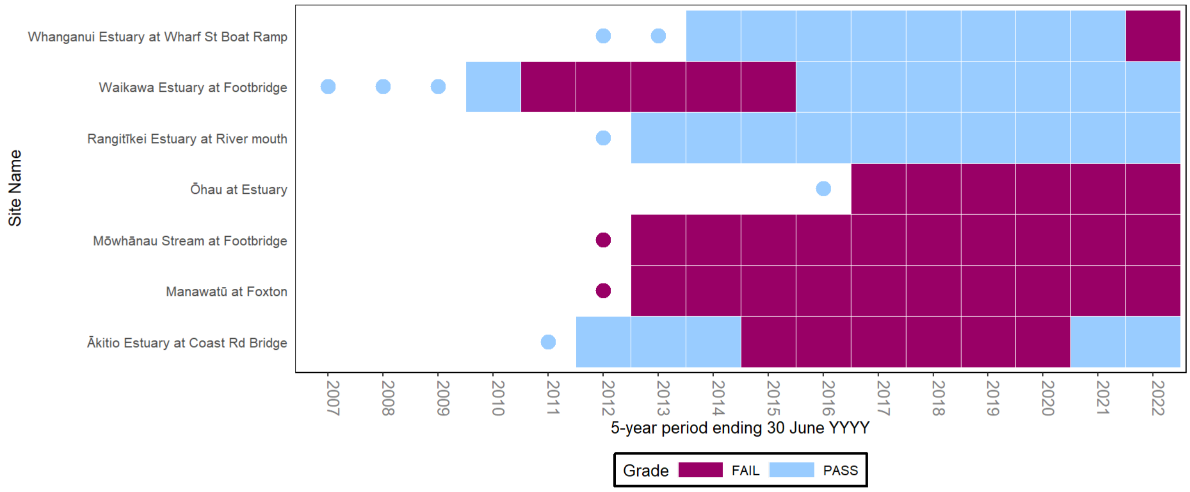

Figure 101: Rolling state assessment for One Plan temperature target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C6 Coastal

C6.1 Chlorophyll-a

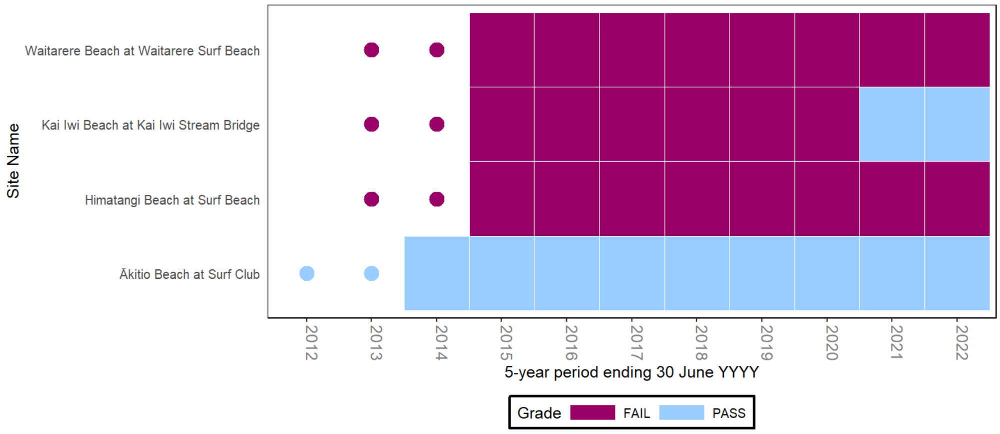

Figure 102: Rolling state assessment for One Plan chlorophyll-a target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C6.2 Faecal coliforms (median)

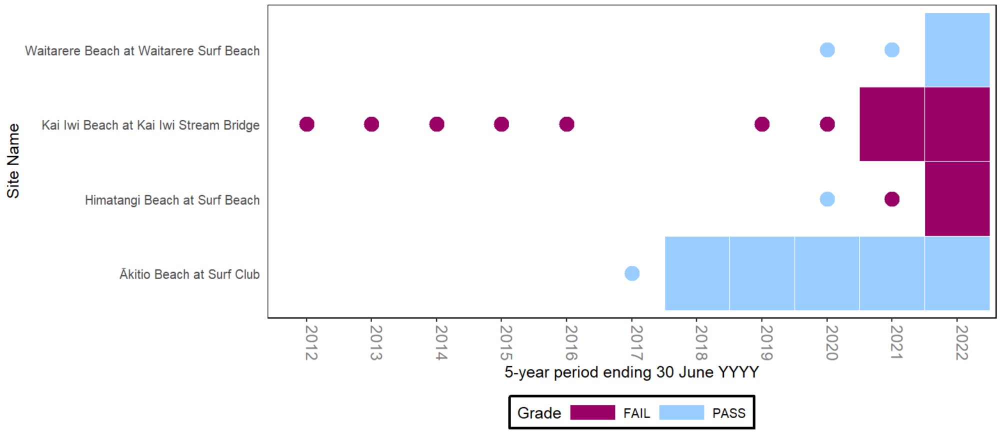

Figure 103: Rolling state assessment for One Plan faecal coliforms (median) target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C6.3 Faecal coliforms (q90)

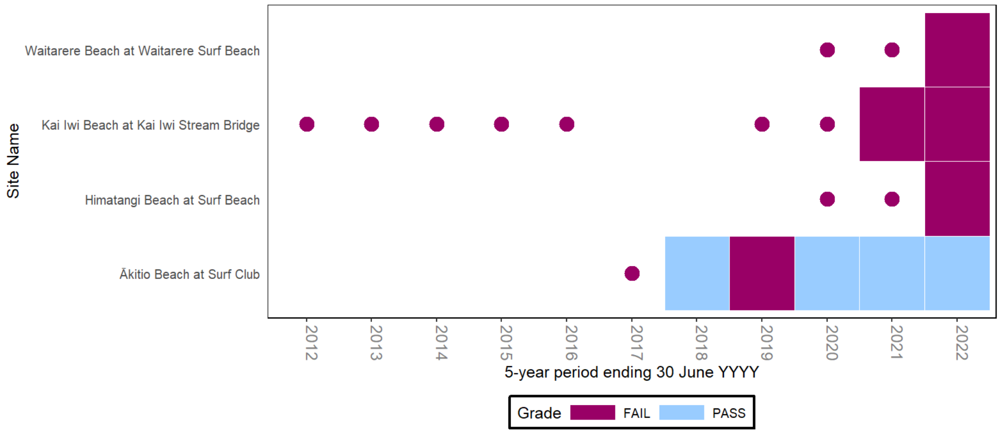

Figure 104: Rolling state assessment for One Plan faecal coliforms (q90) target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C6.4 NH4-N

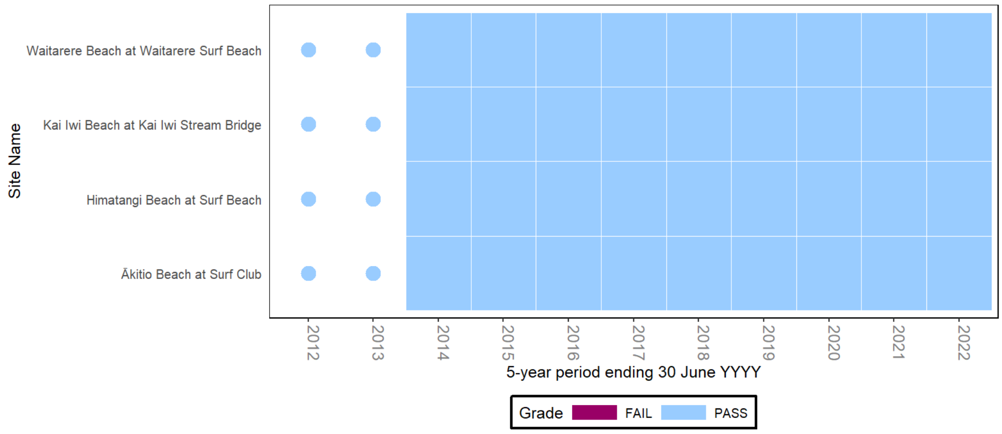

Figure 105: Rolling state assessment for One Plan NH4-N target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C6.5 TN

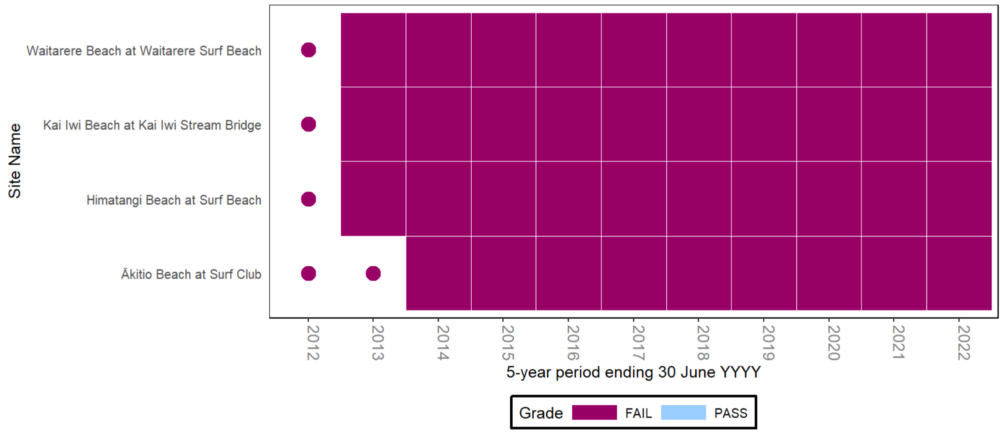

Figure 106: Rolling state assessment for One Plan TN target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

C6.6 TP

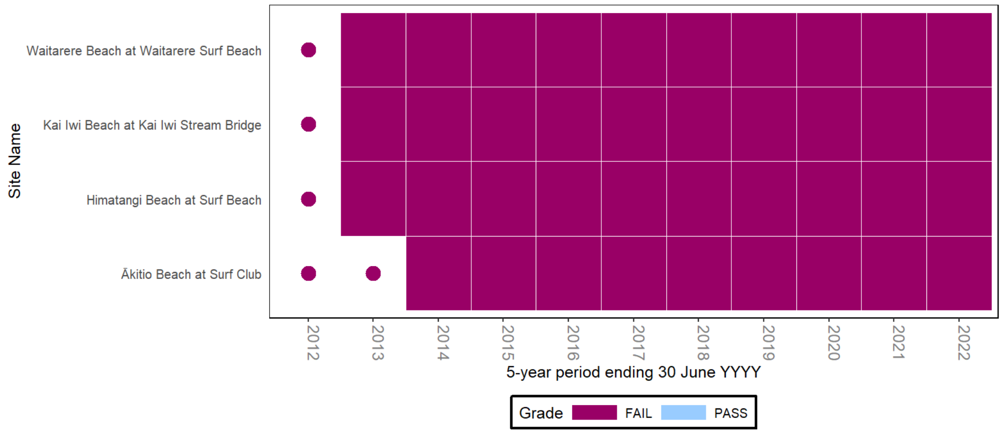

Figure 107: Rolling state assessment for One Plan TP target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

Appendix D Scatter plots of state versus trend

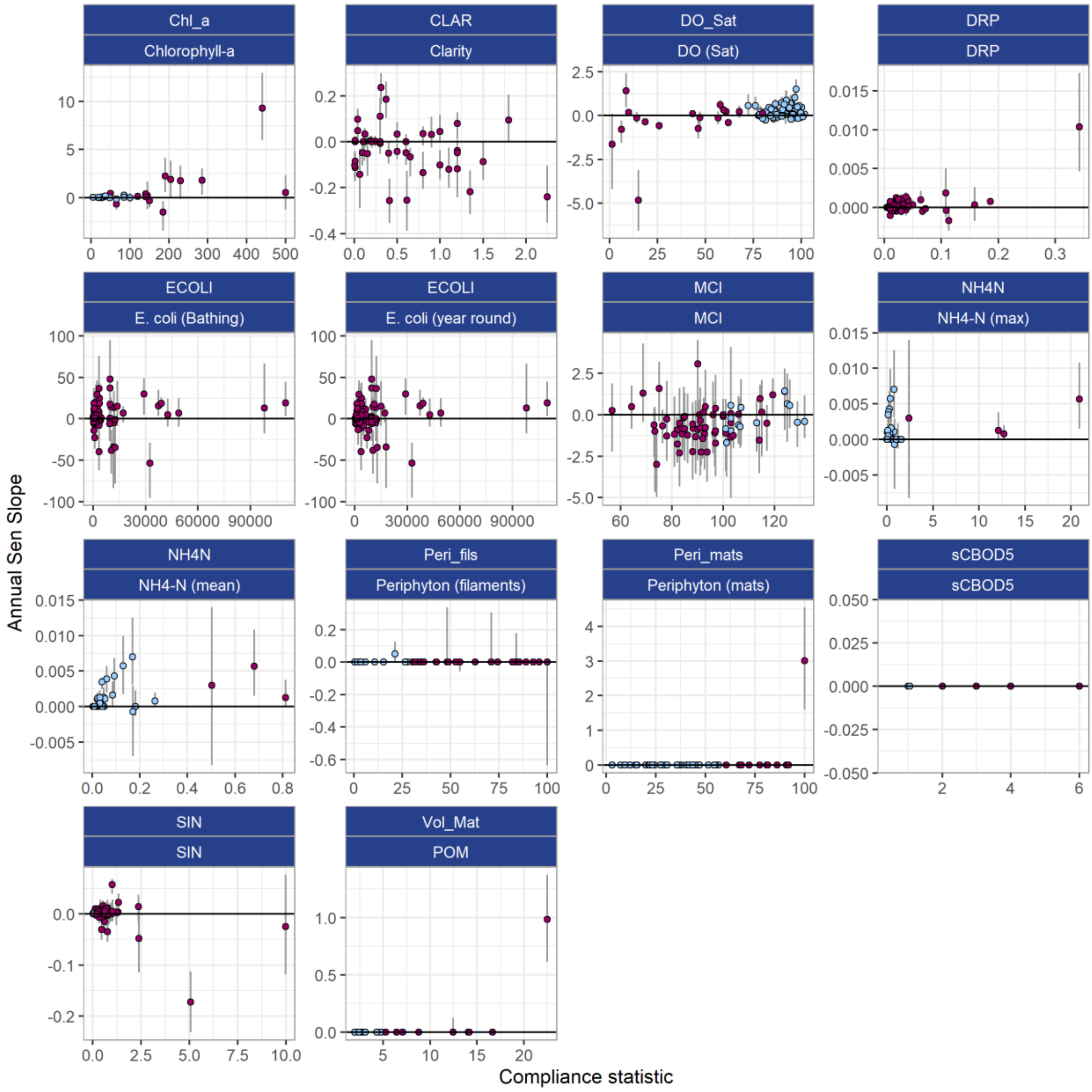

Figure 108: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at river SoE sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

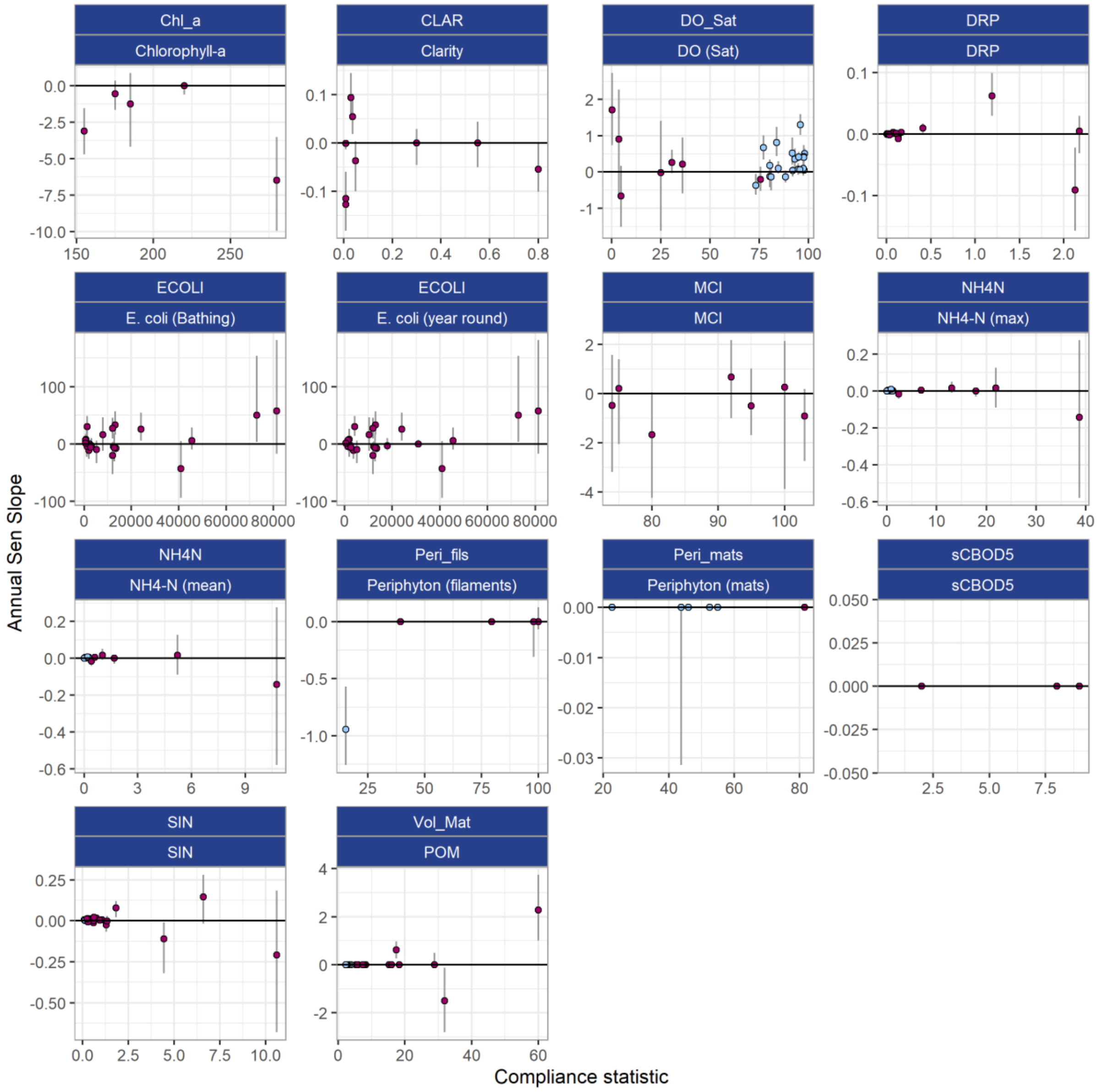

Figure 109: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at river impact sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

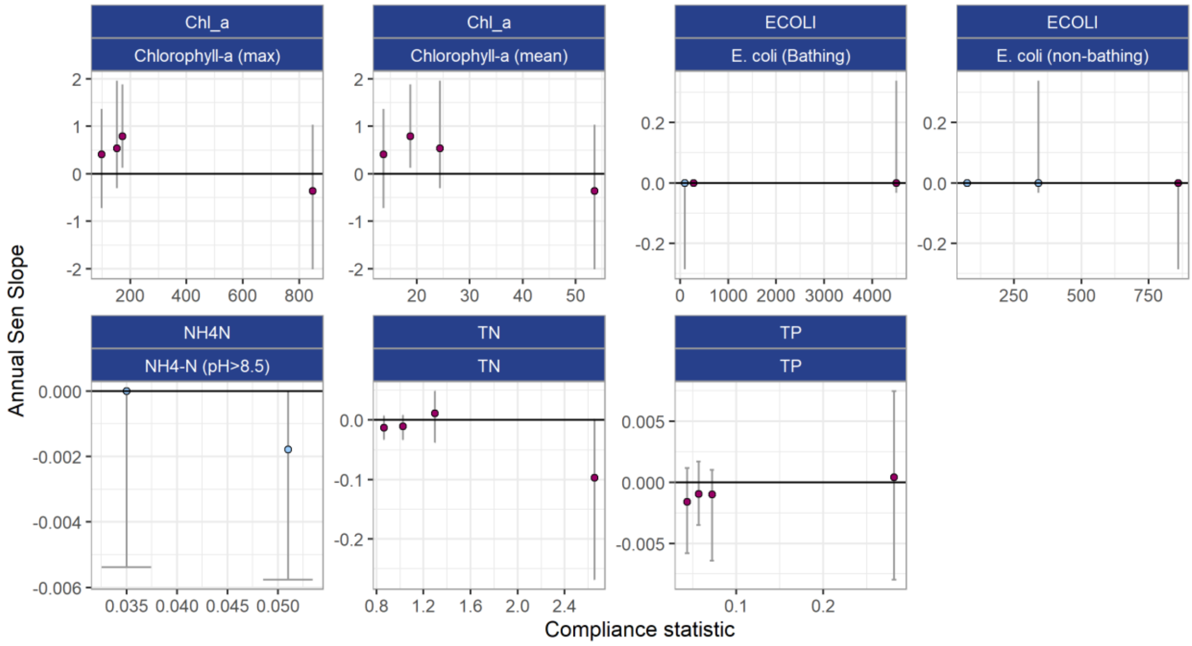

Figure 110: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at lake sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

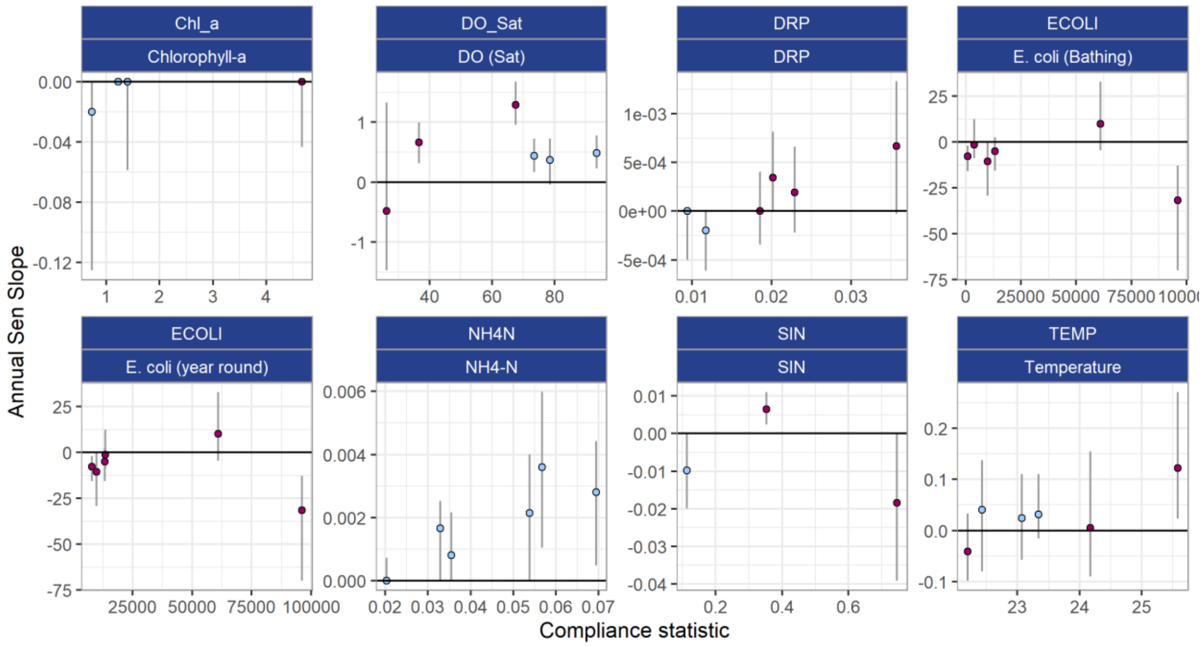

Figure 111: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at estuary sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

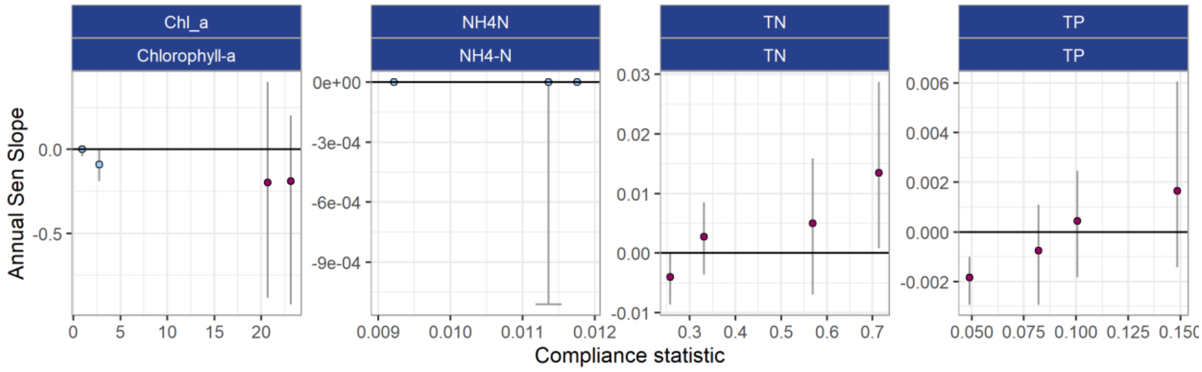

Figure 112: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at coastal sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

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